Catching Up through Divergent Paths: Technology Innovation and Institutions in Africa and Asia

Banji Oyelaran- Oyeyinka
Professorial fellow UNU-MERIT
Director, Monitoring and Research Division, UN-HABITAT

1.0 Introduction

This paper explores two broad themes and advances one proposition. At a general level, we seek to understand the factors that explain the wide differences in economic growth through divergent paths of development between East Asia and Sub-Saharan Africa. The aim is to contribute to the debate on the underlying factors of historical catch-up, an idea that has a long tradition of scholarship (Hamilton, 1791; List; 1885; Gerschenkron, 1962, Amsden, 1989, 2004; Schumpeter, 1934, 1950; Reinert, 2004). The second theme examines the processes of technological capability accumulation through learning that is now widely accepted as underpinning historical economic catch-up (Nelson and Winter, 1982; Rosenberg, 1986, 1994; Freeman, 1987, 1989; Amsden, 1989; Lundvall, 1988). In taking a comparative historical economic perspective, we are not unmindful of the deep rooted differences in the history and cultures of the regions and countries as well as the political constituencies and policies that shape the paths of development (see North, 1993). We feel that these differences may in fact help to shed light on our analyses. We therefore assume *a priori* following Adelman (2001:128) that the "development trajectory of countries is not only non-unique but also malleable"[1].This informed the title of the book[2] from which much of the materials in this paper is extracted. Simply put, the paths of development of nations are uneven in the sense that countries chart unequal trajectories depending on where they came from, the processes they adopted (path-dependence), the natural endowment they possess and its consequences for sectoral specialization patterns (Leamer *et. al*., 1999).

The broad proposition is that explicit investment in technological capability acquisition, an activity that is central to modern economic development, is underpinned by unique and nationally distinct set of institutions and organizations. In other words, industrialization is not simply about the purchase of machinery or simply increasing investment in research and development (R&D). If this was the case, the rich mineral and oil producing countries of the world would not need to exert much effort in achieving modernization. It is also not just about adopting manufacturing as a policy over say, agriculture or mineral processing[i]. The factors that shape the paths of development are rather complex but there a few areas of agreement, namely: that knowledge, not just technological alone in its narrow sense, is critical; that certain leading sectors are able to propel economies in the direction of high growth dynamics; that learning through diversity generation (this is triggered in economic systems through innovation) foster economic development; and that diversities of institutions and systems of production (and innovation) explain the persistent differences in the path of development and ultimately the economic outcomes of national endeavours (Schumpeter, 1942; Gerschenkron, 1962; Lundvall, 1988; Dosi et al, 1988). In other words, sectoral specificities are an outcome of policy decisions arising from political constituencies shaped by the mediation of initial conditions at the

[1] This book assumes that policies and institutions are context specific and may be relevant only for a specific time. For instance institutions that East Asians countries employed in early stages of catch-up to achieve unprecedented export success may be irrelevant at another time. Global rules of the game have changed and new actors have emerged to change the dynamics of trade and other exchange relations.

[2] Uneven Paths of Development by Banji Oyelaran-Oyeyinka and Rajah Rasiah (forthcoming, 2007, Edward Elgar, UK).

manner of integration of host sites in the world economy, institutional development and therefore of the learning and the direction for knowledge accumulation.

The paper compares industrial development through technological advance in a number of Sub-Saharan African (SSA) countries with selected East Asian Countries (EACs). While Sub-Saharan African and East Asian countries have been compared in the past, the studies have focused largely at broad macroeconomic levels[3]. However, no study that we know of has approached this subject from the perspective of learning and technological capability building. Again, while East Asia has been studied in respect of its "miracle", studies on SSA have invariably been coded in terms of the "tragedy" of economic failures and regress[4]. While there are empirical facts to justify both approaches, our focus is different; and ***we look neither to tragedies nor miracles but to learning***. The country studies rely on evolutionary economic theorizing applied to specific sectors that have been influential in stimulating economic growth. Twenty years ago, no one could have predicted that electronics hardware would be the key driver of rapid growth of China. Neither could anyone have foreseen that India would become a major exporter of software.

This new dynamic in Asia has implications for both trade and development in Africa. Much of East Asia has become fully engaged in global trade in manufacturing and value adding services while Africa remains connected largely through the supply of raw materials. Significantly, the terms of trade and volume as well as the destination of raw materials exports are experiencing geographical shifts, by which Africa is progressively exporting more to Asia and in the process, fueling growth in the continent. But this might happen at the expense of nascent local manufacturing capacity where all efforts are directed at feeding the new factories and workshops of the world based in East Asia. For instance, China and much of East Asia have tremendous strength in low-tech production such as in consumer electronics and computer peripherals, footwear and apparel and clothing. Africa has a fairly long history in textile and garment manufacturing, and there is some promise of electronics manufacturing in South Africa, Nigeria and Mauritius. The African Growth Opportunities Agreement (AGOA) with the United States in 1999 and the 'everything but arms' agreement between least developed economies (LDEs) and the European Union in 2001 has given some room for the emergence of foreign-driven garment manufacturing in a number of Sub-Saharan economies, but only at the expense of displacement of the older garment manufacturers in these economies. In the background of these agreements is the removal of the Multi-Fibre Agreement (MFA) in 2004. Available evidence shows that much of the AGOA- and EU-related garment manufacturing remained uncertain and the firms involved pay low wages without social safety instruments (see Ganesh, 2006).

There is therefore much that connects Africa and Asia and there are lessons of contemporary and historical relevance to be learnt. However, what are of utmost interest for this paper are the lessons that our comparative institutional study holds for better understanding of theory and policy that promote industrialization in latecomers.

The paper is organized in five sections. The next section sets out a brief theoretical framework while section three reviews the global trends of the IH sector. Sections four and five explain the reasons for divergent evolution of industry.

---

[3] Past studies include *Asia and Africa: legacies and opportunities in development* (Lindauer and Roemer 1994), *Asian industrialization and Africa* (Stein 1995), *Africa and Asia in comparative economic perspective* (Lawrence and Thirtle 2001) and *Comparative development opportunities of Sub-Saharan Africa and East Asia* (Nissanke and Aryeetey 2003).

[4] See World Bank (1989) for the former and Easterly (1989) for the latter.

2.0 Innovation in Latecomer development

There is little doubt that knowledge by itself and embodied in different mediums (as human agents, codified information, new machinery and equipment) particularly with the advent of the internet has been spreading at an unprecedented rate but it is equally true that large swathes of the globe are being left behind. While knowledge bridges are occurring so are also knowledge divides. The spread of the internet across countries as well as the adoption of related artefacts such as computers and the common telephone gives an indication of the skewed growth of human knowledge. But what lies behind the uneven generation and diffusion of knowledge and with it unequal development is the diverging development of knowledge appropriating and creating capabilities. Put differently, what factors separate the countries that made rapid progress in "catching up" and those that "fell behind"? This question has remained central to economists for decades (Marx, 1860; Mill, 1844; List, 1885; Veblen, 1915; Young, 1928; Schumpeter, 1912; Kaldor, 1957; Lewis, 1956; Myrdal, 1957; Gerschenkron, 1962; Amsden, 1989)[ii]. There are three broad identifiable historical catch-up paths (clearly there will be others) following from Veblen's account of Germany's industrialization, Gerschenkron's institutional historical approach and the more recent account of Japan and other East Asian successful industrialization (Johnson, 1982; Freeman, 1987; Fransman, 1985; Amsden, 1989; Amsden and Chu, 2003; Mathews, 2002; Wade, 1990; Chang, 1994, 2003; Reinert, 1994). The stylized facts of the catch-up stories are as follow:

- The occurrence of earlier industrialization of forerunners provide an opportunity for *latecomers* to initiate their own processes of industrialization through learning; not just to imitate the technological process but also to configure new and context-relevant "institutional instruments" (this is the term used by Gerschenkron).
- This process of catching-up demands an institutional arrangement that is peculiar to the endowment of the particular country. The institutional instruments include financial incentives[iii] to overcome the scale effects of increasingly complex industrial plants, and the instruments to remove the barriers imposed by the state of education of society are notable ones. As Abramovitz (1986) puts it: "The state of education embodied in a nation's population and its existing institutional arrangements constrains it in its choice of technology". Institutions exert pervasive influence in a country's catch-up process; it defines its future as much as it defined its past.
- The catch-up strategy has almost always succeeded through the targeting of rapidly growing sectors, an advice that was taken seriously the East Asia starting with Japan.[iv]
- Catch-Up involves an activist state; however the role of the state will differ in style and content across countries and time. In Japan for example and later South Korea, the use of financial instruments of the state ("directed credit") was deep and pervasive. In Taiwan the rise of the country's semiconductor industry was spearheaded by a combination of state-promoted policies. The Industrial Technology Research Institute (ITRI) was a key actor while public-private research consortia proved to be an effective institutional instrument in developing laptop PC (Matthews, 2002).
- The nature of demand has also been critical in catch up strategies (Malerba, 2006). Domestic demand was critical in driving scale-based industries in large economies such as the United States, Germany, Japan and Korea. However, export-oriented industries were central to all successful industries in Taiwan.

3.0 The Information Hardware Sectoral System

Due in part to the complexity of treating national systems all at once particularly in a multi-country study, we have selected for study a sector characterized initially by low value added and employment-intensive operations where East Asia has made significant progress, that is the manufacturing and export of computer hardware. With the exception of a dynamic economy in Japan that had already reached the technology frontier in industries such as shipbuilding, steel, textile and garments before the mid-19th century to act as a driver of the East Asian economies, in some ways like Africa, the labour force and institutions in the remaining East Asian economies were also weakly developed initially.

But what justify the selection of the computer hardware sector for study within such contrasting regional settings and with such vastly different institutional capacities (and growing wider) are the five main reasons:

(i) Global growth is currently driven by knowledge-intensive industries (Lall, 2003). At the heart of this "new economy" are ICTs which are in turn driven by rapid advances in information and computer systems. Africa and other developing countries would have to take account of this new global dynamics and understanding how it works is an essential start.

(ii) Our approach is to examine the industry within a systemic framework by which the complex interactions of actors involved not just in design and manufacturing but also in assembly and test, packaging, distribution, marketing and services of computers and components. In a global division of labour, all countries have an entry point in this complex products system as increasingly "knowledge creation" is separated from manufacturing systems.

(iii) Beyond design and assembly of computers, the role of the Internet as a General Purpose Technology (GPT) has spawned a variety of new IH appliances including web phones, game consoles, and so on through which countries that are far from the global locus of manufacturing (USA, Taiwan, China) could benefit from value-adding services, which offers African countries considerable opportunities to generate wealth through fruitful networking with Asia.

(iv) African countries presently have to compete intensely in their home countries with scale-driven products exported from Asia. It is important in an unpredictable world to understand the policy and institutional context of how this competition will be shaped.

(v) The processes of learning are expected to drive firms in African countries to move beyond assembly and processing or simply selling computer hardware.

The aim of the study was not to demonstrate how African countries could or should acquire capability development in IH manufacturing and design. The main objective is to understand the underlying dynamics of the convergence of institutional, technological and policy factors that shape a latecomer country's attempt to learn from the forerunners to generate economic wealth in a globally competitive sector.

The evolution of the IH sub-sector in East Asia has its roots in production relocation (largely Singapore, Malaysia, Philippines, Indonesia, Thailand, China and Vietnam) as well as market and technological linkages (Korea and Taiwan) with multinational firms in the United States. Essentially a new global locus of production is emerging which is driven in large part by state actions and strong intermediary links between firms and institutions historically (Amsden and Chu, 2000; Ernst, 2006; Rasiah, 2001) and sustained by a host of market and non-market phenomena (regional systems, global networks) (Gereffi, Humphrey and Sturgeon, 2005; Rasiah and Lin, 2005).
This new global division of labour has created a new Information Hardware (IH) divide with:

- The diffusion of IH into technology-using industries such as textile and garments, and wood and furniture in East Asia has transformed the dichotomy between old and new economies. The diffusion of enabler technologies such as IH, materials and mechatronics by technology creating modern (high tech) industries into traditional (previously considered low tech) industries are increasingly removing such dichotomies.

- East Asia continues to attract investment in IH production while Africa and the rest of developing Asia remain as importers. Expansion in the production of export-oriented IH in the transitional economies of Eastern Europe and the continued production operations in Latin America has not slowed down the rapid expansion of production in East Asia (see Rasiah, 2004).

Studies have shown that IH has impacted with varying levels of intensity on traditional sectors such as textiles and garments although the impact seems to be more profound in the sector itself which is also the biggest employer of IH skills. Particularly computer use has been more concentrated in services (aviation, banking, and financial services) as well as manufacturing. For instance, Computer Aided Design/Computer Aided manufacturing (CAD/CAM) systems are widely used for pattern designing, fabric cutting and stitching and colour identification. Also, layout and organizational innovations have resulted in considerable IH applications in supply chain management for more efficient warehousing and inventory control, reduction in defects and logistics costs, and more effective qualitative and quantitative demand-supply coordination (between producers and users). For example, integrated materials resource planning (MRP2) has successfully transformed just-in-time production to lower defects and delivery times while absorbing customer taste effectively in both producer-driven value chains (e.g. automotives) and buyer-driven value chains (e.g. garments and computers). In some cases it has driven modularization to smoothen production coordination in supply chain management (Gereffi, Humphrey and Sturgeon, 2005; Rasiah, 2006). In some cases it has quickened the introduction of design changes and strengthened the capacity of shrinking production space to deliver a wider range of product models (Rasiah, 1994). Coordination between small and medium enterprises (SMEs) and large retailers in the US and Europe (Nordstroms, Wal-Mart, Nike) has been facilitated by IT through continuous flow of information on design, orders, stock levels no matter the geographic locations. These developments have transformed garment value chains so much that in some cases producers coordinate manufacturing, packaging and logistics without affecting buyers' (brand holders) position as drivers of the chains (see Rasiah, 2007). In some cases, logistics operators act as the interface between producers and buyers to reduce lead times in the garment industry. African countries have in the main been spectators and at best imitative peripheral actors in this new global order although things are beginning to change.

A number of Asian countries have progressively become key players in the manufacturing of IH products although the depth of capabilities, market orientation and the nature of actors vary across countries. For instance, China and Malaysia have a mixed structure where firms produce for both domestic and global markets and are engaged in low value added production of components, modules and computers). Singapore specializes in foreign-driven high value added operations in wafer fabrication, designing and logistics (Mathew and Cho, 2000; Wong, 2005). Taiwan specializes in original equipment manufacturing (OEM), R&D and in the supply of global services (see Rasiah and Lin, 2005; Ernst, 2006). Understanding how this new production and innovation dynamics evolved is essential for our understanding the subject of the next section.

4.0 Information Hardware: Global Leaders and the Rest

This section sets out the main elements of the computer hardware innovation system. Our conception of "sector" is different from the notion of an industrial sector where firms are homogeneous; products are undifferentiated and only distinguishable by the *price*. According to the perfect competition assumption, individual actors have no role to play and it is infinitesimal in the limiting case (Chang, 2003). In other words the action of individual agents or states have no effect on the economic outcome; which also means that interactive learning, so central to the systems concept is irrelevant. Unlike an industrial sector which only consists of firms engaged in the production of sector-specific goods, we define a sectoral system of innovation to include firms and economic agents (including institutions) that connect through market and non-market (e. social and technical relationships that are not price determined) links. It is underpinned by the following: (a) firms (b) organizations that support and regulate (c) networks of actors (d) institutions and (f) knowledge base (Malerba, 2004). Using patent data on European economies Malerba, Orsenigo and Peretto (1997) and Malerba (2002) expanded the sectoral dynamics to explain the persistence of innovations and how they relate to market structure variables. Sectoral systems also allow the understanding of how particular knowledge base drives new innovations (see Malerba, Nelson, Orsenigo and Winter, 2001).

The development of industry-specific knowledge bases sometimes criss-crosses into other industry knowledge bases so that the components of these industries overlap to contain products that can figure any of these industries – e.g. the diffusion of software systems (command navigation systems and smart lights), and electronics components (read only memory chips and other transistors in car stereo sets), as well as precision tooling (e.g. moulds) in motorcar assembly has brought together the machinery, electronics and aerospace industries (see Best, 2001; Rasiah, 2002).

A focus on a specific sector such as IH brings out idiosyncratic issues because of the nature of markets, the paths of innovation and the challenges faced by states differ considerably depending on the composition of the industry, and the embedding institutions. IH has been a leading sector and as will be shown in this chapter, a source of considerable wealth creation for the advanced industrial countries and much of East Asia. Whilst key industries have engineered upswings to initiate economic long waves (Schumpeter, 1934; Perez, 1984), successful developers starting from low income levels and from the bottom of the technology ladder often targeted selected lead sectors on the basis of investment generation and linkage potential (see Hirschman, 1958; 1977). The history of successful latecomer industrialization has also been identified with leading sectors (Gerschenkron, 1962) and the computer hardware sector is part of the electronics complex that has driven the economies of East Asia. The East Asian countries starting with Japan followed later by South Korea and Taiwan have all accumulated capabilities at different levels to become major exporters. Whereas local firms using creative duplication and licensing channels have driven production of computer hardware in Japan, Korea and Taiwan, foreign direct investment has been the prime channel of growth in Singapore, Malaysia, Thailand, China, Philippines, Indonesia and Vietnam.

African countries on the other hand have become major consumers of electronic goods even though a number of them have adopted key components of IH. Table 1.1 shows the indicators of IH knowledge infrastructure and the normalized values of these indicators Basic Internet Infrastructure (BII) calculated over the 1999-2004 period.[v] BII CAGR for China, India and Korea top the Asian countries while Ghana, Nigeria, Tanzania, Rwanda have also been growing very rapidly in Africa. The growth rate in Africa reflects the significant investments being made in telecommunications particularly in GSM.

Table 1: Average Annual Growth Rate, Africa and Asia

Country	Int. User 2004	PC Density 2004	Tel. Density 2004	GDP Growth (1999-2004	BII Growth (1999-2004)
China	72.52	40.88	241.05	7.82	53.09
Hong Kong	505.57	608.34	549.16	2.04	28.32
India	32.41	12.06	40.71	3.98	45.05
Indonesia	7.68	13.88	45.91	0.38	22.37
Korea	2.03	544.92	541.94	3.76	42.63
Malaysia	3.04	196.83	178.60	1.63	18.68
Philippines	3.90	45.13	42.11	1.59	31.29
Singapore	4.89	921.21	439.59	2.18	20.65
Botswana	33.91	45.22	77.13	4.89	31.70
Ghana	16.98	5.16	14.46	2.16	43.45
Kenya	44.81	13.17	8.94	-0.003	17.51
Nigeria	13.74	6.73	7.98	1.08	37.44
Senegal	42.33	21.25	23.13	1.40	33.43
South Africa	78.35	82.18	105.17	1.40	18.31
Tanzania	8.85	7.38	4.27	2.95	53.28
Rwanda	4.27	NA*	2.58	1.40	32.44

*NA – Information not available
Note: Basic internet infrastructure (BII) refers to a composite index of internet users per capita, personal computer users per capita (PC density), and telephone density (Tel). BII = Internet User Index = {X j,i - Min (Xj,i)}/{Max (Xj,i) - Min (Xj,i)}, Xi refers to the Internet user per capita and I, and j refer to the number of countries reporting data.
Data Source: Authors' Calculations from World Development Indicators, The World Bank 2005.

The IH industry is a complex network of firms that can only be fully understood when considered in a global and regional systemic framework. Components of the industry range from microprocessors, peripherals and components to complete systems, operating systems and applications. There are also a plethora of actors (OEMs, ODMs and OBMs) depending on the level of technology and markets. The activities in which actors are involved are complex and diverse such as development of new products, design, production, R&D, manufacturing, assembly, logistics, distribution, sales, marketing, service, and support. They therefore include the largest multinational corporations (MNCs) to local small enterprises.

While the personal computer (PC) has been the flagship of the industry for a long time, the notebook (NB) segment has emerged as a significant component that signals a continuous advance in the evolution of digital technology which is a shift in form factor. Presently, it is the fastest growing segment of the industry, located largely in the United States, Japan, Taiwan and China.

The gradual shift of centres of manufacturing production and increasingly design is one of the hallmarks of development in this sector. The move to the Asia-Pacific region and particularly China has been due to a host of factors. Both push and pull factors working simultaneously have been instrumental in the global spread of manufacturing and design, as well as R&D activities. FDI-driven IH manufacturing began relocating in economies such as Singapore, Malaysia, Thailand, Philippines, China, Indonesia and Vietnam, literate low cost labour in sites endowed with good basic infrastructure, political stability, security and fairly efficient bureaucratic coordination (especially approvals and customs). Singapore managed to stimulate considerable upgrading in the industry through its leveraging strategy. Malaysia, Thailand, Philippines and Indonesia have remained entrenched in low value added operations. Vietnam's experience with IH manufacturing is still short while China has managed to attract both types of operations – low cost operations in unskilled labour abundant sites and fairly high tech operations in science parks.

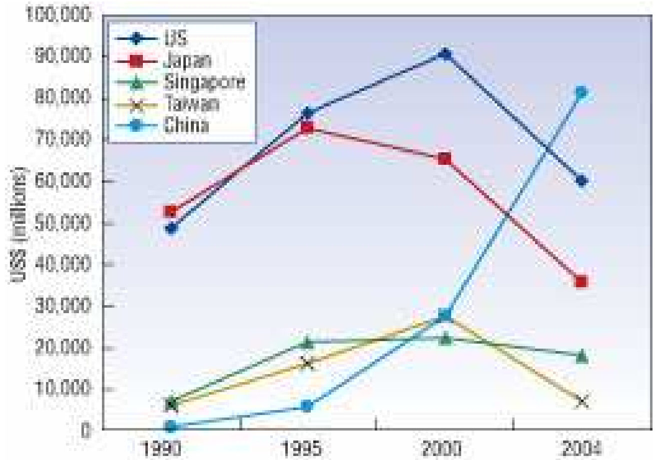
Taiwan and Korea relied on preferential policies to stimulate upgrading in local IH firms, accessing MNC know how through licensing and appropriating learning and innovation synergies through creative duplication (see

Amsden, 1989; Amsden and Chu, 2003; Kim, 1997; Rasiah and Lin, 2005). Taiwan, Korea and China have developed the capabilities to sustain export success. These include the availability of knowledge and skills base, the creation of unique organizational and institutional structures, as well as policy and state coordination that fostered the growth of the sector. Within a period of two decades, IH industry space in the world which had been dominated by US companies is now shared by Japanese, Korean, Taiwanese and Chinese companies.

The dynamics of foreign operations in developing economies have also changed over the years. American, European and Japanese firms only relocated assembly and test operations in East Asia in the late 1960s and 1970s. The decomposition of manufacturing operations that started in the 1980s led to the contracting out of components and completely knocked down parts operations to other American firms. American and European firms subsequently began contracting out wafer fabrication (e.g. Taiwan Semiconductor Manufacturing Corporation and United Microelectronics Corporation), computer manufacturing (e.g. Tatung) and related components to Taiwanese firms from the mid-1980s. OEM operations had become important players in the IH value chain by the early 1990s. American (e.g. Sanmina, Jabil, Flextronics and Solectron) and European (e.g. Infineon) firms too began to participate strongly in these contract operations. Strong deepening in the high tech infrastructure in Taiwan, Korea and Singapore has also helped attract innovation off-shoring by MNCs in these countries (see Prasada, 2000; Ernst, 2006). China has become a particularly attractive location for original equipment manufacturing (OEMs) and contract electronic manufacturing (CEMs) from the USA, Europe and Japan due in part to price competitiveness but significantly because of institutional reforms that raised productivity and provided the platform for a move from simple assembly to packaging, test and design. The Chinese computer hardware industry has for this convergence of factors risen from a peripheral actor to a global producer and exporter over the last one and half decade. As shown in Figure 1, IH production value increased from $645 million in 1990 to $81 billion in 2004, outstripping US production for the first time.

The accelerated growth of Chinese production started a decade earlier and in the process outpaced forerunners such Japan, Taiwan and Singapore (see Figure 1). Chinese hardware production tripled in the last five years.

Figure 1: Leading IH Producing Locations 1990-2004



Source: Reed Electronics Research, Yearbook of World Electronics Data.

China is producing a wide range of IH products including personal computers, servers, desktop PCs and laptop PCs, but excluding mini/micro-computers and workstations).

Significantly, there has been a progressive rise in the share of Asia in IH production and export with an increasing emphasis on a mix of low and high value added products. While the US remains the top exporter of CH and also the destination of most exports, there have been changes in the trends. Tables 2 and 3 show the ranking of the global national leaders in IH production and export.

Although the United States has retained export leadership of IT hardware, China has continued to record the highest growth rate - at almost 40 percent (see Table). China's manufacturing production capacity continues to rise and IH export increased from US$35.2 billion in 2002 to US$49 billion in 2003, and with this China became the second largest exporter to displace Japan and Taiwan to third and fourth places. What is most significant is that while China continues to gain, Japan and Taiwan's shipments fell by 19.2 and 31.4 percent respectively; a significant decline that has widened the gap between them and China. Table 4 and Figure 2 show the rise of export by the Asia-Pacific area and the trend drop in the share of Japanese shipments. The rest of the developing world has also been catching up in high-tech exports but Africa is not an important beneficiary.

Table 2: Domestic Export Value Rankings of World Leading IH Producer Nations

	2000	**2001**	**2002**	**2003**	**03 Growth**
US	85,772	69,605	61,268	62,511	2.0%
PRC	25,535	28,174	35,225	49,075	39.3%
Japan	52,153	39,204	27,673	22,371	-19.2%
Taiwan	23,081	20,124	17,291	11,864	-31.4%
Singapore	16,395	11,173	11,352	11,646	2.6%
South Korea	11,856	9,720	11,449	11,501	0.5%
UK	12,121	10,725	10,121	9,946	-1.7%
Germany	8,657	7,430	6,549	6,430	-1.8%
Mexico	9,400	8,211	8,246	8,297	0.6%
Malaysia	7,236	6,974	6,576	6,861	4.3%
Ireland	6,470	5,670	5,460	5,583	2.3%
France	5,618	4,732	4,334	4,313	-0.5%

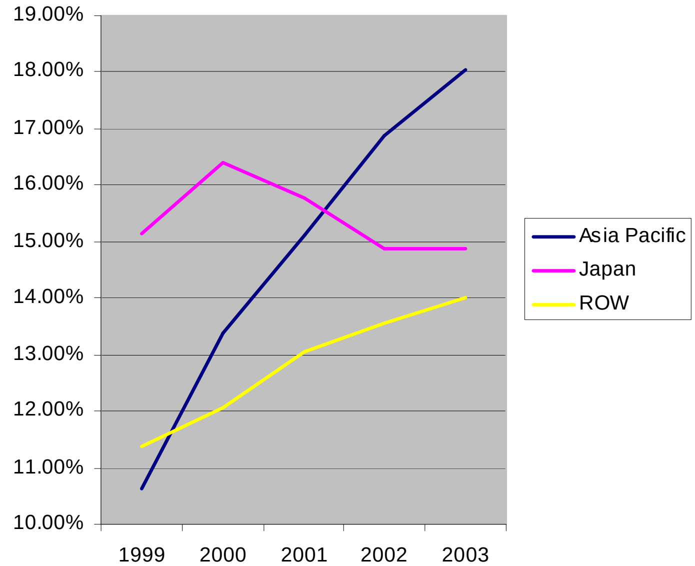
Note 1: "IT Hardware" includes only the shipment value of computers and peripherals
Note 2: As some of the national data in the Yearbook is based on customs statistics, in some cases it includes transshipment trade.
Note 3: The data in this table has been adjusted according to the revised product definitions and national data included in the latest edition of the Yearbook.
Source: JEITA, The Yearbook of World Economics Data, EIAK, KISDI; ITIS Project, MIC (2003.11)

Table3: Exports of IH Hardware by Regions

Export Year	**Global $M**	**Asia Pacific (excluding Japan)**		**Japan**		**Rest of the World***	
		$M	**%**	**$M**	**%**	**$M**	**%**
1999	454,646	43,685	10.63%	59,806	15.15%	46,412	11.37%
2000	502,594	59,190	13.37%	70,745	16.41%	54,021	12.06%
2001	440,394	57,787	15.10%	59,957	15.76%	50,881	13.06%
2002	401,908	58,132	16.88%	52,142	14.88%	48,039	13.55%
2003	413,114	63,171	18.05%	53,488	14.87%	50,714	13.99%

* Rest of the World stands for the rest of the developing world, excluding the U.S. and Western Europe.
Source: Calculated from IDC, November 2004.

Figure 2: Growth of Export Value of Asia Pacific, Japan and ROW regions



Source: Calculated from IDC, November 2004.

Table 4 shows exports of computers and electronics components. For instance in both the SITC 752 and SITC 75997 categories, the share of Taiwan and China in 2000 equaled or surpassed that of a number of Western European countries and these has taken place in two decades. By 2000 East Asian economies accounted for around 50 percent of computer exports. The label of "simple" assembling and "mere copying" is increasingly no more appropriate a description of products and processes of some developing world.

Table 4: Country Shares in World IH Hardware Exports

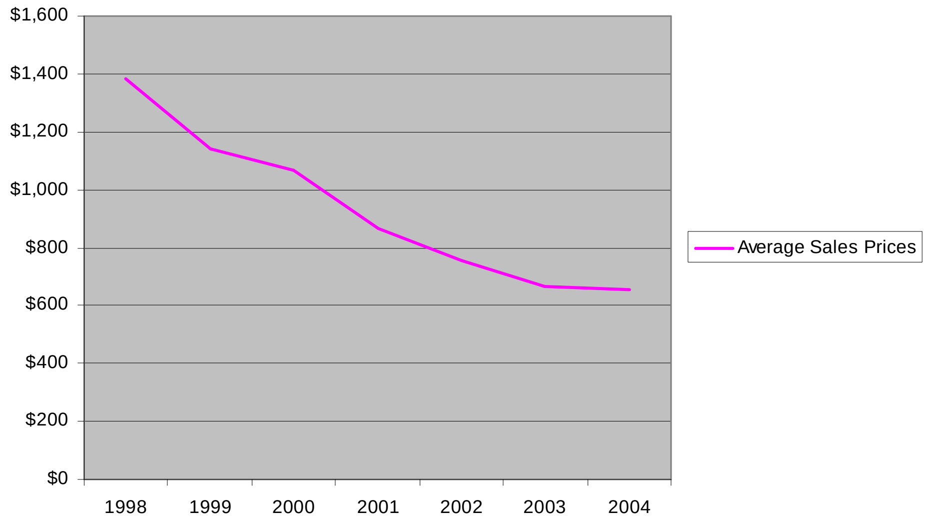
		Shares of World Exports			
		SITC 752 Computers		SITC 75997 Elec components	
		1992	***2000***	***1992***	***2000***
Europe	France	0.05	0.04	0.04	0.02
	Germany	0.07	0.05	0.05	0.04
	Ireland	0.02	0.05	0.05	0.06
	Italy	0.03	0.01	0.03	0.01
	Netherlands	0.04	0.08	0.05	0.05
	United Kingdom	0.09	0.08	0.07	0.04
	Hungary	0.00	0.01	0.00	0.01
Asia	Japan	0.21	0.08	0.16	0.09
	Taiwan	0.07	0.09	0.04	0.09
	Hong Kong	0.02	0.02	0.06	0.07
	Korea Rep.	0.03	0.05	0.02	0.07
	China	0.00	0.06	0.01	0.04
	Singapore	0.13	0.11	0.06	0.08
	Thailand	0.01	0.01	0.03	0.05
	Malaysia	0.00	0.04	0.04	0.00
	Philippines	0.00	0.03	0.00	0.02
Americas	USA	0.23	0.17	0.23	0.18
	Canada	0.02	0.01	0.04	0.02
	Mexico	0.01	0.04	0.01	0.02
	Costa Rica	0.00	0.00	0.00	0.01

Source: UN Trade Statistics

Presently, China has assumed leadership in global notebook production; the output is shared between domestic and foreign multinationals, notably by firms that migrated from Taiwan or managed by Taiwanese. Domestic actors have concentrated productive efforts on the local markets and they have been quite successful at adapting imported technology to satisfy local demands. Due to the huge Chinese domestic demand, there is a significantly high share of foreign and joint-venture firms of close to 75% in China's exports.

The prominence of Taiwanese firms in China's IH sector is a result of declining profit margins[vi] in Taiwan (see Figure 3). However, the locational shift was also aided by a change in the legal constraints that prevented notebook production by Taiwanese firms in China (Foster and Cheng, 2006). Again much of the OEM contract was being moved to China by foreign vendors putting pressure on Taiwanese firms to begin to design their own design capability and additionally look for new markets. From production of peripherals they moved on to PC production. A significant part of the output come out of mainland China, and has risen over the last seven years (see Table 5). Taiwanese firms produced from 78-95% of components and peripherals offshore in 2000 of which 60-90% was produced in mainland China. Taiwanese firms manufactured over 80 and 47 percent respectively of desktops and motherboards offshore. Taiwanese firms' produced 45 percent of desktops and motherboards in mainland China (MIC, 2001).

Figure 3: Average Sales Prices for Notebook Sales in Taiwan



Source: Created from MIC, 2005.

Table 5: Taiwan Firm Production in China

	Offshore production as percent of total[a]			China production 1998	
Type of product	**1995**	**1998**	**2000**	**1998**	**2000**
All products	25.0	43.0	51.7	NA	NA
Components					
Power supplies		91	95	64	90
Keyboards		91	95	59	86
Mice		89	95	74	95
Cases		75	80	45	71
Monitors		71	81	35	60
Sound cards		67	NA	68	NA
Mapping cards		64	NA	64	NA
CD-ROM/DVD/RW		59	78	43	69
Scanners		38	86	32	85
UPS		25	NA	25	60
Graphics/video cards		18	NA	18	20
Motherboards		36	47	34	45
PC systems					
Desktops		89	84	8	45
Laptops		.01	7	0	7

[a]Total production includes production in Taiwan, China, and all other overseas locations (e.g., The Americas, Europe, etc.).
NA – Information not available.
Source: (MIC, 1999b; MIC, 2001).

Among African economies South Africa is the only economy that shows significant numbers of PC exports, albeit even there the numbers provide scant comparison with East Asia. In South Africa PC shipment was 774,784 units during 2002, reflecting a year-on-year growth of 1.5%. During 2002, South African PC market revenues decreased 0.6% year-on-year, to reach R7,774.4 million (BMI-T, 2003).

The strength of the educational and public sector PC spending – as well as a stable small medium business (SMB) sector has been cited as the primary drivers of IT production in South Africa. SMB shipments were up 57.4% year on year in 2002. (BMI,) 2005

In 2004, the top ten vendors together accounted for a 74.5% share of the total PC sales in South Africa. This is up from 72.6% reported in 2003. In revenue terms the top ten held a 79.8% share of the market, slightly down from 80.1% reported in 2003. The top five vendors on the South African PC market in 2004 respectively were: HP, Mustek, Dell, Proline and IBM (BMI, 2005).

5.0 Explaining Divergent Paths of Industrialization

The central proposition of this essay is that due to the diverse set of polities that define learning and innovation in particular industries, countries tend to follow imperfect and uneven paths of industrial and technological evolution. ***Variations in initial conditions, the nature of institutions, infrastructure and state policy support have led to the observed differentiated outcomes***. We applied a systemic framework to understand the drivers of learning, innovation and competitiveness in late development.

In order to understand the process of uneven development shaping the sectoral innovation system within a historical context but using the capability framework, we suggest a typology of sectoral systems that emerged out of the different country case studies. While initial conditions and the accumulation of sectoral knowledge bases are important, governance should emphasize four pillars of the system, viz., basic infrastructure, high tech infrastructure, network cohesion and global integration. A multitude of institutions constitute the four pillars. The selection of an industry and the participation of all critical economic agents in the development of these elements should be coordinated by an actor-focused coordination agency.

5.1 Uneven Outcomes

The path-dependent nature of SIS and the ways in which it has evolved in uneven fashions in the different countries was evident from our study. Initial conditions are important because historical precedent was clearly evident in all the countries; more so, we have proceeded on the a priori assumption that like all industrialization processes the evolution of the IH industry is also an evolutionary process. Institutions and systems are therefore closely connected because they co-evolve. As David (1994, p. 215) observed: "Institutions typically evolve new functions and because these are added sequentially they are shaped by internal precedents".

Sectoral systems are dynamic and they should not be conceived in static terms; we therefore placed country systems within two broad *component band or spectrum*. A sectoral system has a number of components which we set out earlier. For instance, while the Taiwanese IH industry is a more advanced SIS, it is placed in the same band as the Chinese SIS. The first SIS is a dynamic and rapidly learning system, termed *Dynamic System of Learning Innovation (SLI1)*, while the second is a non-dynamic system that is slow to learn, termed *Non-Dynamic System of Learning Innovation (SLI2)*. What distinguishes the two systems are:

- The depth of computer hardware activities (assembling, manufacture, design, systems integration);
- The sophistication of physical and high-tech infrastructure (note the BII);
- Quality of human capital required for CH manufacturing, design and new products; and
- Global integration into the CH value chain.

The sectoral policy focus on IH and related industries directly and indirectly starts from phase two in Table 6 and increases in intensity as regions evolve to the frontier phase. The evidence from the country chapters in the book show that only Taiwan has reached phase four with semiconductor firms participating in frontier research activities in DRAM microchips. Computer and components firms are also engaged in frontier activities in Taiwan. All four systemic pillars are rated highly by both foreign and local firms in Taiwan, though local firms utilize the R&D institutions much more than foreign firms. Indeed, the extensive accumulation of knowledge synergies in the IH industry has been driven systematically through a sectoral policy focus by ERSO.

China is very much in the catch up phase with no firms engaged yet in frontier R&D activities. Although the largest IH firms are only engaged in assembly and test activities, the institutional support in China has evolved to support strong operations in wafer fabrication and developmental research activities. Although design and R&D activities are dominated by local firms, flagship foreign multinationals such as Intel have also started R&D and wafer fabrication activities in China.

Malaysia is very much still in the learning phase in the computer and components industry. A handful of the computer (e.g. Dell) and component firms (e.g. Intel and AMD) in Penang reported participation in developmental R&D but none in Johor. Firms in Penang enjoyed stronger network cohesion and global integrated than firms in Johor. Basic infrastructure in the two states was similar. However, institutional efforts to support a transition to the catch up phase has so far been stalled by poor coordination between the institutions in the high tech pillar and firms (see also Best and Rasiah, 2001).

Without a sectoral emphasis on driving the catch up process, the IH industry is still limited to assembly and test activities in Indonesia, Mauritius, Nigeria and South Africa. Local firms are engaged in the assembly of computers for the domestic markets, as well as, components. The emphasis in Indonesia, South Africa, Nigeria and Mauritiues has largely been confined to the use of ICT. Liberal government policies in these countries have largely failed to encourage domestic capability building. Hence, lacking in institutional support IH manufacturing in these countries have largely been limited to small batch localized assembly of final IH goods such as computers. Hence IH firms are hovering between phases one and two in these countries.

Table6: Policy Focus on Driving Systemic Pillars

	Basic Infrastructure	**High Tech Institutions**	**Network Cohesion**	**Integration in Global Markets**
Initial Conditions (1)	Political stability and efficient basic infrastructure	Critical mass of economic agents	Social bonds driven by the spirit to compete and achieve	Integrated in global economy
Learning Phase (2)	Strengthening of basic infrastructure with better customs and bureaucratic coordination	Import, learning by doing and duplicative imitation. Human capital development	Expansion of tacitly occurring social institutions to formal intermediary organizations to stimulate connections and coordination between economic agents	Access to foreign knowledge through machinery and equipment import and FDI Integration in global value chains
Catch Up Phase (3)	Smooth integration with all institutions in 4 pillars	Import, creative duplication and innovation. Developmental research. Creative destruction is a major source of technological catch up (Schumpeterian Mark I).	Participation of intermediary and government organizations in coordinating technology inflows, initiation of commercially viable R&D	Access to foreign knowledge through licensing, acquisition of foreign companies and imitation. Access to imports and exports. Upgrading in global value chains
Frontier Phase (3)	Novel basic infrastructure support instruments to support short lead times	Basic research (Schumpeterian Mark II system)	Participation of intermediary organizations in two-way flow of knowledge between producers and users	Access to R&D human capital and collaboration with R&D institutions, high tech resources and markets abroad

Source: Authors

The results can be used to explain uneven development of the IH industry. Some of these features are captured in Table 7. Five key dimensions emerge from the evidence from the seven countries. Variations in IH industry development in these countries can be captured under: one, composition in production mix; two demand structures; three, firm-level technological capabilities; three, network cohesion; and four, institutional differences. We explain briefly.

5.2 Compositional Differences

The composition of the IH industry varies in all the countries examined. Taiwan enjoys leadership in almost all the IH products manufactured by firms in these countries. Manufacturing in Mauritius and Nigeria are confined strictly to labour-intensive assembly of a limited range of IH goods such as computers for the domestic market.

Following successful upgrading and rising production costs Taiwanese firms relocated the labour-intensive segments of assembly and test operations of IH component, CKD and CBU to Southeast Asia initially from the mid-1980s but especially China from the 1990s. Hence, Taiwan managed to support upgrading with human capital deepening in the IH industry dominated by SMEs initially.

With a huge domestic market and the world's largest labourforce, China has attracted major multinational corporations and spawned domestic firms into a range of IH activities in the country. Unlike the small size of the labour force and landspace, China's sheer size has attracted component, high end and integrated operations. Almost all the leading IH multinationals have both low end and high end operations in China, and in addition local firms have acquired IBM and entered into IC design, fabrication and assembly of a number IH CKDs and CBUs. Indeed China has low assembly operations in locations such as Pearl river Valley and High end operations in places like Shenzen and GanSu.

In Malaysia, multinational-driven component manufacturing in low value added assembly and test has still dominated IH operations. Multinationals assemble a range of micro-chips, ink cartridge and printers, capacitors and resistors, monitors and motherboards. Only a handful of multinational firms assemble computers, motherboards, scanners and monitors (Dell, Acer and Agilent) and one has been engaged in wafer fabrication in 2006 (Infineon).

None of the foreign IH hardware firms in Indonesia, Mauritius, Nigeria and South Africa are engaged in microchips and designing activities. The focus is still very much on low value added activities. Some firms have entered computer assembly, and in hand phone assembly in all four countries. However, the focus is on assembly of local brands which are all sold in the domestic and regional markets. Both the CKD and CBU computer assemblers in Mauritius and Nigeria largely sold their brands in the local market with some exports going to other African countries. Semiconductor firms are still absent in these countries. Imports still dominate domestic demand in IH products in these countries.

Despite enjoying superior infrastructure and human capital compared to Indonesia, Mauritius and Nigeria, the lack of industrial policy support in IH development has reduced South Africa to being largely an importer of IH products. Although the level of capabilities achieved fall below firms in Taiwan and China, some South Africa's IH firms have achieved multinational status.

5.3 DEMAND CONDITIONS

Demand coordination has been a critical driver in the growth of sectoral production systems. The prime demand drivers in the growth of IH firms in the Asian and African countries examined vary considerably.

China by far enjoys the largest domestic market and labour force, and hence has attracted the largest production base. Multinationals engaged in the assembly and test of IH products supply the domestic market as well as export. Local firms engaged in wafer fabrication and designing activities largely sell in the domestic market. However, China's production and export structure is diversified extensively and hence no one – including IH products – enjoys export shares reaching 15 percent (see WTO, 2006).

China's large domestic market (income per capita is a rough guide to the size of market and they differ significantly in the two sectoral systems) has provided a strong stimulus for innovation (Kline and Rosenberg, 1986). Amsden (1977, 1985) had presented insightful accounts of the machine tools sector in Taiwan which point attention to the ubiquitous ways in which the *size* and *type* of markets shape the rate of knowledge creation as well as the division of labour. The 'extent of market' or 'size of market' refers to the purchasing power, rather than to a geographic area or large population but "the capacity to absorb a large annual output of goods"[1]. Amsden makes a distinction between the notion of 'size' and 'type' of market. Two markets of equal purchasing power may be qualitatively different in their capacities to consume large amounts of goods[1]. Markets in the three African countries have relatively small size (thrive on personal exchanges of kinship relations, personal loyalty and social connections)[1] and fits in very many respects markets characterized by low profitability, limited economies of scale and low intensity learning that slows long run technological capability building, see table 8.

Table 8: Markets and Institutions in Latecomer Countries

	Institution Signal	*Technology Signal*
Size of Market	Impersonal exchange, low purchasing power,	Low economy of scale
Type **of Market**	Low income economic units, structural rigidity, low aggregate demand	Low degree of specialization, low innovation demand, low intensity learning slows knowledge division of labour
Orientation **of Market**	Impersonal exchanges Signal competitive institutions in well functioning markets while personal exchanges perpetuate inefficient and costly transaction.	Foreign demand signals high quality, high specialization and increases division of knowledge labour. Low domestic-oriented demand structure slows productivity growth, learning and innovation.
Other Characteristics of Latecomer Markets	• Low per capita income and high price elasticity: a disincentive to consume high quality goods; • High entry costs for small firms.	Delays evolution to high quality production and slows specialization and innovation. Demanding markets calls forth process and product innovation.

Despite active interventions, industrialization in Taiwan has been driven by export demand. The IH industry itself grew with strong integration in export markets. Contract manufacturing for exports dominated the evolution of Taiwanese firms from OEM to ODM and OBM activities. The export-intensity shares of IH firms in Taiwan have been high. As production costs increased the labour intensive segments of IH manufacturing were relocated in Southeast Asian from the mid-1980s and China from the 1990s.

The foreign ownership dominated IH industry in Malaysia is also integrated strongly in export markets. IH products constituted over 50 percent of Malaysia's exports in 2005 (see WTO, 2006). Giant multinationals helped connect Malaysian exports to global buyers. Although the domestic market has increased its absorption of intermediate demand (e.g. components and CKDs) and final demand (example Dell computers), export markets has remained the prime propellant of IH growth in Malaysia.

Indonesia has a dual structure with multinationals relying on export markets and domestic computer firms focused on supplying the domestic market. Foreign firms are dominated by low end assembly operations for regional buyers in Singapore and Johor.

Mauritius is characterized by the smallest domestic market. The Nigerian market is larger and hence supports more domestic assembly of IH CBU products such as computers. Although some local brands are exported to the African continent production of IH CKDs and CBUs are largely geared to the domestic market in both countries. The same conditions apply in South Africa.

5.4 UNEVEN TECHNOLOGICAL CAPABILITIES

Firms in the IH industry in the seven countries examined show different levels of technological capabilities. The knowledge and technological capabilities demanded by these operations are very uneven. Only Taiwan has reached the frontier with the R&D capability to design and engineer frontier semiconductor chips. For example, the microchips engineered and fabricated by TSMC are among the key drivers of IH CKDs and CBUs. Taiwanese firms also have the capacity of produce OEM, ODM and OBM versions of IH products. Chinese firms are headed in that direction with involvement in such operations but presently still largely utilize microchips to assemble Chinese OEM, ODM and OBM IH products. Firms in Malaysia are largely confined to assembly and test operations of components and IH CKDs. A handful of firms assemble IH CBUs such as computers and fabricate low end wafers. IH Firms in Nigeria, Mauritius and South Africa are limited to assembly of IH products for the domestic market. Apart from software firms in South Africa, IH firms are not engaged in high end operations in the three African countries studied.

The key human capital capabilities required to stimulate innovation at the frontier in IH firms are technicians, engineers and scientists. The segments in IH value chains comprise: (1) product design, (2) component manufacturing, (3) assembly, (4) software development, (5) marketing, and (6) distribution. Each of these sub-stages require a combination of different kinds of knowledge and skills of actors from various disciplines, some as diverse as physics, informatics and computer science are required to facilitate innovation. The demand of engineers and scientists is highest in the stages of product design and software development.
Although some CBU assemblers in the IH industry in Mauritius and Nigeria undertake designing activities, the technological capabilities of these firms hover around labour-intensive and imitational capabilities. Lacking in scale and lock-ins with lead firms as well as effective institutional support, local firms in these countries have simply absorbed and internalized prevailing technology to assembly computers and mobile phones for the domestic and African continental market. These products lack the quality and price to compete in major export markets.

IH firms in South Africa excel in especially software technology. However, these firms connect little directly with local IH manufacturing operations. Instead software firms largely support the service sector providing software solutions in South Africa and the regional market.

Overall, IH firms in Taiwan and China clearly either already at the technology frontier or show clear movement towards it. IH firms in Malaysia are at an impasse for over a decade now as institutional weaknesses has restricted firms' movement to the catch up phase. ***The lack of effective industrial policy*** has prevented IH firms in Indonesia, Mauritius, Nigeria and South Africa from locating themselves in the IH manufacturing trajectory, though the last has both human capital and market networks to make the transition.

5.5 UNEVEN NETWORKING AND COORDINATION

The nature of connections and coordination between economic agents – firms and institutions influence production and innovation synergies. Geographic space represents knowledge bases but these have manifested differentially in the different systems (Saxenian, 1994; Rasiah, 1994, 2002; Oyelaran-Oyeyinka and McCormick, 2007). An industrial cluster is a dense sectoral and geographical concentration of enterprises comprising a multiplicity of actors such as producers, suppliers, users, and traders. When an agglomeration of enterprises exhibits strong attributes of an innovative cluster it becomes more than a geographic space where firms co-locate. In such a cluster, we have strong inter-firm interaction and specialization (Best, 2001; Rasiah, 2002;).

Strong clustering is associated with high rates of learning and knowledge accumulation that continually alter the knowledge base of the cluster. In addition there is a demonstrable evidence of a dense network of formal and informal institutions in Taiwan (see Rasiah and Lin, 2005). (Clustering in Taiwan, China and Penang in Malaysia show evidence of high connectivity and coordination and hence, high economic performance. Clustering in Johor in Malaysia, Indonesia, Mauritius, Nigeria and South Africa exhibit weaker degrees of inter-firm collaboration, lower intensity of learning and have poorly developed institutions (Oyelaran-Oyeyinka and McCormick, 2007).

Clusters in Taiwan, China and Penang in Malaysia are strongly integrated in global factor and final product markets. Among the seven countries examined only Taiwan exhibits integrated networks throughout the country. Even then there are wide regional differences in the character of these clusters in China and Malaysia dictated in the main by their differential knowledge characteristics. For example, Penang in Malaysia is better networked then Johor in Malaysia. Although the manufacturing bases are concentrated in the Guangdong, Jiangsu, Fujian province and Shanghai, Beijing main cities, in these regions production is localized in three locations including Yangzi River Delta, Pearl River Delta and Loop Bo Sea Region, which have transformed into the computer manufacturing industrial clusters in those regions. However, the three areas are defined by different knowledge features; for instance, Pearl River Delta has very strong costal manufacturing base based on import processing, Loop Bo Sea Region is the most highly knowledge-intensive region with large number of low cost science and technology personnel, while Yangzi River Delta combines the above two factors, although it does not have as much concentrated knowledge base as Loop Bo Sea Region.

The nature and intensity of cluster cohesion achieved in these economies also differed. For instance, active involvement of the state government and its successful attempt to bring together the critical economic agents to coordinate their security, production, buyer-supplier, training and distribution needs helped spawn the birth of new firms and technology flow to other firms in Penang. However, the hands-off approach to industrial coordination by state development corporations outside Penang (Malaysia) limited their capacity to promote inter-firm relationships. The uneven roles—the more interventionist role of the Penang Development Corporation in Penang and the hands-off role of other state development corporations after firms obtained their operating licenses—resulted in uneven outcomes (see Rasiah, 2002). Consequently, the strength of the systems in regional clusters differs significantly, even within a single country.
In Mauritius and Nigeria organizations to, *inter alia*, promote interactions emerged and though the chambers of commerce has enjoyed growing numbers the coordination involved is still very underdeveloped. There are also weaknesses in connections between IH firms and basic institutions such as power and finance suppliers.

South Africa provided a different experience. Lacking in industrial policy support to stimulate IH manufacturing the South African government especially at the regional level has encouraged strong networking to encourage IT use across the country. Especially software firms have mushroomed through such networks to support IT services in South Africa.

Overall, Taiwan has enjoyed the strongest networking – formally and informally - among the concentrations of IH firms among the seven countries. China and to a less extent Penang in Malaysia have also enjoyed fairly strong connections and coordination among the critical agents. The extent of network cohesion among IH firms in Johor, Malaysia, Indonesia, Mauritius, Nigeria and South Africa have been less but regional locations have supported strong integration in software segments in South Africa.

5.6 INSTITUTIONAL SUPPORT POLICIES

The policy frameworks supporting IH industries in the seven countries can be examined through two sets of institutional categories, vi.z basic infrastructure and high tech infrastructure. Given the differential drivers and their consequences it will be appropriate to examine them separately. Neo-liberal advocacy drove the provision of good basic infrastructure in most of these economies – especially in export processing zones.

Basic institutions

Taiwan (from the 1960s), Malaysia (from the early 1970s), China (from the 1980s) and Indonesia (from the 1990s) introduced FDI policies by providing basic infrastructure at export processing zones. The provision of security, smooth customs, beaureacratic and investment coordination, repatriation guarantees of profits, liberal ownership conditions and coordination of utility suppliers, and the access to low wage but literate and trainable labour acted as a big incentive to attract large scale labour-intensive operations from abroad. Tax holidays helped augment further the attractions of these sites. By and large the export processing zones in China, Malaysia and Taiwan has managed to provide excellent basic infrastructure.

Malaysia remains a good example of a country that has done well in providing good basic infrastructure to attract labour-intensive IH activities. Indonesia has managed to provide this following the leasing out of Batam's export processing zone to Singapore owned Temasik Holdings. However, security considerations and customs problems have discouraged further expansion of IH activities in other parts of Indonesia.

The lack of financial incentives and weaknesses in infrastructure to support short lead times and knowledge-intensive operations has discouraged large scale export-oriented assembly activities in Mauritius and Nigeria. Also, investment coordination for IH firms remain poorly developed in these economies. In fact, foreign ownership is low in IH activities in these countries.

Several regions enjoy excellent basic infrastructure in South Africa. However, the lack of special financial incentives to attract FDI into IH manufacturing has discouraged the relocation of FDI-driven IH component, CKD and CBU firms in South Africa. Hence, much of the IT firms in South Africa are confined to local owned software operations supporting the service sector.

High Tech Institutions

There exists much higher variance in policies supporting high tech institutions than basic institutions in these countries. Whereas strong basic insititions are critical to coordinate labour intensive low value added activities upgrading to higher value added activities require similar support from high tech institutions.

Taiwan has managed to support IH firms' participation in strong creative accumulation activities. From low value added activities government policy transformed in the 1970s to support upgrading through investment in high tech institutions. The initial targeting from government came from the creation of the Industrial Technical Research Institutes (ITRI) in 1973, which led to its electronics wing – ERSO – driving catch up in electronics technology. The acquisition of RCA in the late 1970s and subsequently the joint-venture with Philips in 1986 helped Taiwanese firms incubated in ERSO to make the catch up in DRAM and ASIC technology. Other IH firms also made significant strides in technological catch up in components, CKD CBU products through support from ERSO, the facilities offered at Hsinchu Science Park and the science and technology policy grants (see also Mathews and Cho, 2000; Rasiah and Lin, 2005). Smooth coordination and the participation of firms in the development of human capital in technical institutes and universities, and R&D coordination with university and other labs (e.g. ERSO) has helped strong movement of Taiwanese firms to the technology frontier.

In China the support for catch up activities has become strong. Although foreign multinationals have relocated wafer fabrication and R&D operations in IH activities in China, much of the design activities are limited to local firms. Nevertheless, institutional support has successfully driven catch up in these firms. Indeed, among other examples, Lenova's acquisition of IBM's computer manufacturing division has also assisted catch up in the industry. Like in Taiwan strong coordination with university courses and R&D labs has also helped firms movement in the technology ladder.

In addition, human capital policies in Taiwan and China were coordinated strongly with upgrading: mastering modern production and manufacturing capabilities with engineers as well as skilled technicians and mastering design and re-design of already matured product. Engineers rather than research scientists tend to dominate this set of activities. The locus of activity here is the factory and manufacturing centers.

Taiwan and China have thus been able to deepen these activities through the graduation of IH firms progressively from OEM to ODM and finally to OBM activities. Another critical step is the shift into the design and engineering of components which involves systematic engineering and scientific specification of products, processes, systems including computer hardware and software. The importance of design was shown by the evolution of the Chinese computer hardware which literally took off on the wings of re-design rather than simply learning to produce[vii]. The acquisition of IBM's computer manufacturing division by Chinese owned Lenova was a major step in the catch up process here, which is symptomatic of the Schumpeterian Mark I system of creative destruction.

The opening of the Malaysian Institute of Microelectronics Systems (MIMOS) in 1985 and the Action Plan for Industrial Technology Development (APITD) of 1990 and subsequent institutional development offered considerable promise for a catch up to occur in the IH industry in Malaysia. However, institutional failures have restricted the effectiveness of these institutions. Unlike China and Taiwan, incentives for building capabilities and for stimulating higher level manufacturing and R&D activities have not been well developed in Malaysia.

The lack of proactive policies to support upgrading activities in IH manufacturing in Indonesia, Mauritius, Nigeria and South Africa means that these countries have remained without a significant concentration of IH firms.

From our typology, the observed differences in SIS has as much to do with policy choices and initial conditions as it is with institutional evolution all of which influence economic performance (North, 1996).[1] The comparative study carried out by Nelson (1993) on national SIs showed that countries generally develop different knowledge bases in both R&D and the capacity for innovation. For instance, he noted the differences that size makes in SIs: "The differences in the innovation systems reflect differences in economic and political circumstances and priorities {while} size and the degree of influence matter a lot" (Nelson, 1993: 507). In other words, policy political choices in a given institutional context influence the shape and direction that the sector takes. Table 9 sums up the state of the different systems.

Table 9: Comparative Sectoral Systems of IT

Country	**Actors**	**Prime operation in Value Chain**	**Policies**	**Institutions**	**Organizations and Network Forms**
China	MNCs and local firms	Integrated operations with R&D, and labour intensities assembly operations	JVs between local and MNCs; central and provincial government demand to stimulate local production; etc… Strategic Interventionist	Rules change to integrate research and industry; to convert military to civilian research centres, unique laws to form quasi public-private business partnerships	Economic zones that form high-tech clusters; state-like enterprises that operate with measures of business autonomy etc…
Taiwan	World class local firms	High Value added R&D driven operations	Strategic Interventions to drive upgrading	ERSO, Hsinchu Science Park play important role in driving learning and innovation	Highly developed and integrated IH Cluster
Malaysia	Dominated by MNCs	Labour-intensive assembly	Incentive driven	MIMOS is a failure in driving learning and innovation. MITI's success in coordinating investment continues to sustain MNC-driven assembly	IH Clusters. Failed incubators
Indonesia	Dual structure: MNC assemblers of components; Local computer assemblers	Labour-intensive assembly	Liberal with no emphasis on IH manufacturing. Promotion of ICT use.	No specific instrument to promote IH manufacturing	
South Africa	MNCs Local Assembling	Labour-intensive assembly	Liberal with no emphasis on IH manufacturing. Promotion of ICT use	No specific instrument to promote IH manufacturing	Designated zones or regions
Nigeria	Local assemblers	Labour-intensive	State procurement but	Weak knowledge base and	Spontaneous Cluster

		assembly	weak policy	poor institutions of finance	
Mauritius	Local Service Producers	Labour-intensive assembly of computers	Policy towards services	No specific instrument to promote IH manufacturing	Designated but underdeveloped IH incubators

Source: Authors

6.0: SUMMING UP

The Information Hardware sector is made up of complex production sub-systems underpinned by structures of knowledge comprising closely located clusters as well as with knowledge bases in far-flung locations all over the world. The path of innovation generation is uneven and is characterized by constant changes as the sector develops including making difficult policy choices. Low income countries are often disadvantaged in terms of cognitive and geographic proximity to knowledge bases and markets because the sector thrives on links with global knowledge systems in order to access technical and scientific expertise. Local firms drove catch up in the IH industry in Taiwan. Multinationals have dominated IH manufacturing in Malaysia. Export-oriented IH manufacturing in components and CKD products in Indonesia are dominated by multinationals but local firms dominated ownership of computer and mobile phone assembly for the domestic market. Local firms dominate manufacturing in Mauritius and Nigeria, which is largely targeted to the domestic market. Despite strong basic infrastructure and software capabilities, IH goods are largely still imported from abroad to South Africa.

In addition to links with global networks, local links with key actors have been important particularly for Taiwan and China. China has turned what could have been an institutional burden to a dynamic advantage illustrating in very direct ways, the impact of initial conditions. The role of scientific and technological manpower built up in the communist era in China and the quality of pre-existent national human and industrial capabilities meant for other purposes such as the military was successfully transformed to commercial IH production. The institutional transformation of the relationship between universities/research institutes and the IH industry that subsequently emerged from them illustrates the persistence of institutions and the power of path dependent development. In Institutional deepening in Taiwan – especially strong high tech institutions and cohesive integration between firms and these institutions was instrumental in firms upgrading to OEM, ODM and OBM operations.

Policies that reintroduced generous tax incentives and the maturation of Malaysia's labor force, combined with imports of cheap foreign labour from Indonesia and Bangladesh led to the relocation of labour-intensive low value added firms in Johor, Malaysia. The synergies created by these firms, as well as the high costs of operations in Singapore, attracted IH component and CKD assembly firms from the 1990s to Johor. Even though China and Vietnam began to offer attractive financial incentives to all firms in 1998 on the basis of investment ensured that several labour-intensive multinationals stayed in Malaysia. However, this strategy along with ineffective coordination with upgrading institutions has restricted Malaysia's capacity to follow Taiwan and it has now been overtaken by China in the technology ladder. Quite evidently, knowledge bases, strategic policy choices, initial conditions, differentiated coordination mechanisms and institutions exert considerable impact on the evolution of sectoral systems.

REFERENCES

Abramovitz, M. (1956) "Resource and Output Trends in the United States since 1870", *American Economic Review*, 46, pp. 5-23.

Amsden, A.O. 1985. The Division of Labour is Limited by the Rate of Growth of the Market: the Taiwan Machine Tool Industry in the 1970s, *Cambridge Journal of Economics*, vol. 9, no. 3, pp. 271-284.

Amsden, A. (1989) *Asia's Next Giant: South Korea and Late Industrialization*, (New York, Oxford University Press).

Amsden, A., Tschang, T. & Goto, A. (2001) "Do Foreign Companies Conduct R&D in Developing Countries", Working Paper No. 14, (Tokyo, Asian Development Bank Institute).

Amsden A.O. and Chu W.W. (2003) *Beyond Late Development Taiwan's Upgrading Policies*, Cambridge: MIT Press.

Audretsch, D. (2002) "The Dynamic Role of Small Firms: Evidence from U.S.", *Small Business Economics*, 18(1-3), pp. 13-40.

Barry, Frank., Van Egeraat, Chris. August 2005. The Eastward Shift of Computer Hardware Production: How Ireland Adjusted. Paper prepared for presentation to conference on "Relocation of Production and Jobs to CEECs: Who gains and who loses?", Hamburg, 16-17 September 2005.

Bell M. and Pavitt K. (1995) "The Development of Technological Capabilities", in I.U. Haque (ed), *Trade, Technology and International Competitiveness*, World Bank: Washington DC.

Best, M. 1990. *The New Competition*, Cambridge, Harvard University Press.

Best, M. 2001. *The New Competitive Advantage*, Oxford, Oxford University Press.

Booth A. (1999) "Initial Conditions and Miraculous Growth: Why is South East Asia Different from Taiwan and South Korea", *World Development*, 27(2): 301-322.

Dhanani S. (2000) Indonesia; Strategy for Manufacturing Competitiveness, Vol. II: Main Report, UNIDO/UNDP Project, Jakarta.

Brusco, S. 1982. The Emilian Model: Productive Decentralisation and Social Integration, *Cambridge Journal of Economics*, vol. 6, no. 2, pp. 167-184.

Ernst, D. and O'Connor, D. 1989. *Technology and Global Competition: the Challenge for Newly Industrializing Economies*, Paris, Organization for Economic Co-operation and Development.

Ernst, D. 2003. "Global Production Networks and Local Development", Research Proposal, *mimeo.*

Ernst D, Ganiatsos T. and Mytelka L. (eds) (1998) *Technological Capabilities and Export Success: Lessons from East Asia*, London: Routledge.

Ernst, D. and Guerrieri, P. 1998. International Production Networks and Changing Trade Patterns in East Asia: the case of the Electronics Industry, *Oxford Development Studies*, vol. 26, no. 2.

Figueiredo, P.N. (2002) "Learning processes features and technological capability accumulation: explaining inter-firm differences", *Technovation*, 22, pp. 685-698.

Figueiredo, P.N. (2003) "Learning, capability accumulation and firms differences: evidence from latecomer steel", *Industrial and Corporate Change*, 12(3), pp. 607-643.

Freeman, C. (1989) "New Technology and Catching-Up", *European Journal of Development Research*, 1(1), pp. 85-99.

Hirschman A. (1958) *The Strategy of Economic Development*, New Haven: Yale University Press.

Hirschman A. (1970) *Exit, Voice and Loyalty: Responses to Decline in Firms, Organizations, and State*, Cambridge: Harvard University Press.

Hobday, M. (1995) *Innovation in East Asia*, (Cheltenham, Edward Elgar).

Kim, L. (1997) *From Imitation to Innovation*, (Cambridge, Harvard Business School Press).

Kim, L. (2003) "The dynamics of technology development: lessons from the Korean experience", in: S. Lall & S. Urata (eds), *Competitiveness, FDI and Technological Activity in East Asia*, (Cheltenham, Edward Elgar).

Kim, L. & Nelson, R. (eds) (2001) *Technology, Learning and Innovation: Experiences of Newly Industrializing Countries*, (Cambridge, Cambridge University Press).

Krueger, A.O (ed.) 1981. *Trade and Employment in Developing Countries*, Chicago, The University of Chicago Press

Lall S. and Streeten P. (1977*) Foreign Investment, Transnationals and Developing Countries*, Basingstoke: Macmillan.

Lall S. (1992) "Technological Capabilities and Industrialisation", *World Development*, 20(2): 165-186.

Lall, S. (1996) *Learning from the Asian Tigers*, (Basingstoke, Macmillan).

Lin, Y. (2003) "Industrial Structure and Market-Complementing Policies: Export Success of the Electronics and Information Industry in Taiwan", ADB Working paper series, Manila.

List, F. (1885) *The National System of Political Economy*, (London, Longmans, Green & Company).

Lundvall, B.A. (1988) "Innovation as an Interactive Process: From User-producer interaction to the National System of Innovation", in: G. Dosi, C. Freeman, G. Silverberg & L. Soete (eds), *Technical Change and Economic Geography*, (London, Frances Pinter).

Lundvall, B.A. (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, (London, Frances Pinter).

Mai, C.C., Wang, J.C. and Tsai, K.H. 2002. "Innovation and Economic Development: the Case of Taiwan's Information Electronics Industry", working paper, Taipei: Chung-Hua Institute for Economic Research.

Malaysia (2004) "Science and Technology data", *unpublished*, (Kuala Lumpur, Ministry of Science, Technology and Environment).

Mathews, J.A. 1995. *High-Technology Industrial Development in East Asia: the Case of the Semiconductor Industry in Taiwan and Korea*, Taipei: Chung-Hua Institute for Economic Research.

Mathews, J.A. 1996. "High Technology Industrialisation in East Asia", *Journal of Industry Studies*, vol. 3, no. 2, pp. 1-77.

Mathews, J.A. 1997. "A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry", *California Management Review*, vol. 39, no. 4, pp. 26-54.

Mathews, J.A. & Cho, D.S. (2000*) Tiger Technology: The Creation of a Semiconductor Industry in East Asia*, (Cambridge, Cambridge University Press).

Mathews, J.A. (2005) "The intellectual roots of latecomer industrial development", *International Journal of Technology and Globalization*, 1(3/4): 433-450.

Nelson, R.R. & Winter, S.G. (1982) *An Evolutionary Theory of Economic Change*, (Cambridge, Harvard University Press).

Nelson, R. (ed) (1993) *National Innovation Systems*, (New York, Oxford University Press).

Okamoto Y. and Sjoholm F. (2003) "Technology Development in Indonesia", in S. Lall and S. Urata (eds), *Technology Development in East Asia,* Cheltenham: Edward Elgar.

Oyelaran- Oyeyinka, B. (2003) "Human Capital and Systems of Innovation in Africa", in: M. Muchie, B.A. Lundvall & P. Gammeltoft (eds*), Putting the Last First: Building Systems of Innovation in Africa*, (Aalborg, Aalborg University Press).

Rasiah, R. (2004) "Technological Capabilities in East and Southeast Asian Electronics Firms: Does Network Strength Matter?", *Oxford Development Studies*, 32(3), pp. 433-454.

Rasiah R. (2007) "Human Capital and Cluster Synergies: The Case of Penang and Jalisco", A. J. Scott and G . Garofoli (eds.) *Development on the Ground: Clusters, Networks and Regions in Emerging Economies*, London : Routledge.

Rasiah R. and Lin Y. (2005) Learning and Innovation: Market, Trust and Government in the Development of the Information Hardware Industry in Taiwan", *International Journal of Technology and Globalization*, 1(3/4): 400-432.

---

[i] For instance, and increasingly, the so-called "low-tech" sectors (salmon in Chile for instance) revolutionalized by new technologies, are increasingly been used as sources of wealth generation. Also see Von Tunzelmann and Acha (2005).

[ii] The catch-up challenge has recently occupied the attention of leading economists working on innovation and technological change. Through the Globelics and "Catch-up" groups, the latter initiated by Richard Nelson, several research projects are presently being carried out across regions. Also see Faberberg (2005) for a summary of the debate from which this section draws.

[iii] Gerschenkron's famous example is Germany's use of investment banking as an institutional instrument to foster industrialization. He equally alluded to the forms of state support in Russia as another. In recent times, East Asian countries have deployed an array of institutional instruments that co-evolved with targeted industries. As Mathews and Cho (2000:187) puts the case of Taiwan: "The Taiwanese approach to the upgrading of technological capabilities within industry has been pursued using innovative institutional frameworks over the course of three decades. These frameworks have co-evolved with the industries they fostered. The major sources for leverage have been training and engineering development; multinational investments and joint ventures; institutional support infrastructure such as the Hsinchu Science-based Industry Park;… innovation alliances; and government coordination".

[iv] The latecomer history of East Asia is replete with successful stories of how in relatively quick succession, South Korea and Taiwan followed the leader Japan in electronics and automotive production. For details of the East Asian experience, see (Amsden, 1989, 2003; Mathews and Cho, 2000) among others.
[v] The BII is a component value of Internet User Index (Int. User/1000), Personal Computer/1000 (PC Density) and Telephone User/1000. The index was calculated by normalizing the values and the Compound Annual Growth Rate found over the 1995-2004 period.

[vi] It is the nature of "technological revolutions" that there is a gradual lowering of costs over time, Freeman and Soete (1997).

[vii] For instance in this category, 13% of S&E manpower is employed in the US, while close to 20% work in non-S&E fields of project management and related areas.