From Knowledge Dependence to Knowledge Creation: Industrial Growth and the Technological Advance of the Japanese Electronics Industry

ABSTRACT

The thrust of the argument put forward in this paper is that the postwar technological advance of the Japanese electronics industry was in essence a product not a primary cause of industrial growth. We demonstrate that the industry's surge forward resulted from the interaction of a unique combination of political, economic and cultural forces. Business leaders took full advantage by investing on a massive scale in physical, organizational, human and technological resources. It was success in the marketplace and strong cash flows that allowed Japanese firms to import technology on a large scale, invest in scientists and engineers, and progressively develop world class technological capabilities. In establishing themselves as global players, Japanese electronics firms moved over the years from a position of knowledge dependence to one of knowledge creation. We explore how this transformation was achieved and how they learned to control and exploit knowledge creating systems and processes. In particular, we establish the multi-faceted context and complex set of relationships that have conditioned strategic decision making and the creation of technological capabilities.

From Knowledge Dependence to Knowledge Creation: Industrial Growth and the Technological Advance of the Japanese Electronics Industry

INTRODUCTION

The rise of the Japanese economy from the rubble of defeat in the Second World War may no longer be viewed as 'miraculous', but it remains a phenomenon that is imperfectly understood. Lewis, Fitzgerald and Harvey (1996, pp. 55-110) amongst others, have provided a convincing synthesis of the process of economic regeneration and development that resulted in an annual average compound rate of growth in real GDP between 1950 and 1992 of 6.7 per cent, a figure which dwarfs those for rival industrial economies such as Germany (4.3 per cent), France (3.8 per cent), the USA (3.3 per cent) and the UK (2.4 per cent) (Maddison, 1996, p. 32). On the supply side, Japan is seen to have benefited from a large, highly skilled and disciplined labour force that for long accepted relatively low wages in return for continuous employment. Equally, the Japanese demonstrated the importance of discipline and social restraint in preferring to save and invest rather than consume both at the individual and corporate levels (Sato, 1987). Relatively low wages and the desire to save and accumulate combined to provide the wherewithal for capital investment and output growth on an unprecedented scale. On the demand side, Japanese industry was well positioned to take advantage of the postwar liberalization of the international economy and the western boom in consumption. Meanwhile, the domestic market, while not closed to foreigners, was informally protected to the extent that the producers of both consumer and industrial goods could more or less guarantee to recover development costs on the basis of domestic sales alone. Such favourable

supply and demand conditions were necessary to rapid industrial growth, but they were not in themselves sufficient. What crucially made for success was that Japanese firms had what was needed to take advantage of favourable circumstances. They invested heavily in plant and equipment to capture economies of scale and scope. They continuously refined methods of working to win productivity gains and improve product quality. They acquired and developed the technologies needed to introduce a stream of new products and manufacturing processes. And, finally, they created organizations with the flexibility to change and adapt to new circumstances and events, eventually moving beyond the shores of Japan to build international business empires.

This explanation of Japanese economic success in the postwar era, while conforming to the available macro- and micro-economic evidence, does not tell the whole story. As Maddison (1995) has pointed out in a different context, it is important to distinguish between the *proximate* and *ultimate* causes of economic growth. Proximate causality refers to the inputs and techniques that directly bring about growth, whereas ultimate causality refers to the institutional, historical, cultural and policy factors that underlie the more immediate proximate causes. It is relatively easy to identify and quantify the impact of proximate causes of growth (the supply and demand side factors noted above, for example), but the ultimate causes of growth almost invariably remain more mysterious and less amenable to measurement. This is because when looking at the proximate we are mainly concerned with the hard and tangible outward expressions of a phenomenon, but when in search of ultimate causality we are more concerned to discover historical determinants, institutional relationships and cultural origins, which are altogether more elusive, harder to circumscribe and pin down.

This article is concerned with one aspect of the search for a more complete understanding of the growth and development of the Japanese economy in the postwar period. The main topic is the creation of leading edge technological capabilities within the Japanese electronics industry, one of the pillars of the postwar economy and an industrial success story of the first order. From a position of chronic depression at the end of the Second World War, the industry entered into a period of sustained development that proceeded virtually unbroken before the entry of the Japanese economy into stagnation during the early 1990s. Year-on-year growth, at rates in excess of 10 per cent for most years between 1950 and 1990, saw Japanese firms rise to the fore in international markets. In 1990, the value of output of the Japanese electronics industry was a staggering $164,854 million compared to $154,625 million for Europe as a whole and $211,471 million for North America. Within the field of consumer electronics, Japanese firms had won a massive advantage, with sales valued at $30,570 million compared to $12,271 million and $6,382 million for Europe and North America respectively (EIAJ, 1993).

In establishing themselves as global players, Japanese electronics firms moved over the years from a position of dependence on foreign technology to one of technological leadership. In this article we explore how this transformation was achieved and how Japanese electronics firms have learned to control and exploit knowledge creating systems and processes. We distinguish throughout between the proximate and ultimate sources of industrial growth. In particular, we seek to establish the multi-faceted context and complex set of relationships that have conditioned strategic

decision making and the creation of technological capabilities. We begin by analyzing the proximate causes of industrial growth and put forward a simple interpretive model. In section 3, the analysis is deepened through a discussion of the ultimate (historical, cultural and political) sources of industrial growth. This enables us in section 4 to contextualize and explain the movement from knowledge dependence to knowledge creation. We conclude in section 5 by analyzing the outcomes and implications of the growth and technological advance of the Japanese electronics industry since 1945.

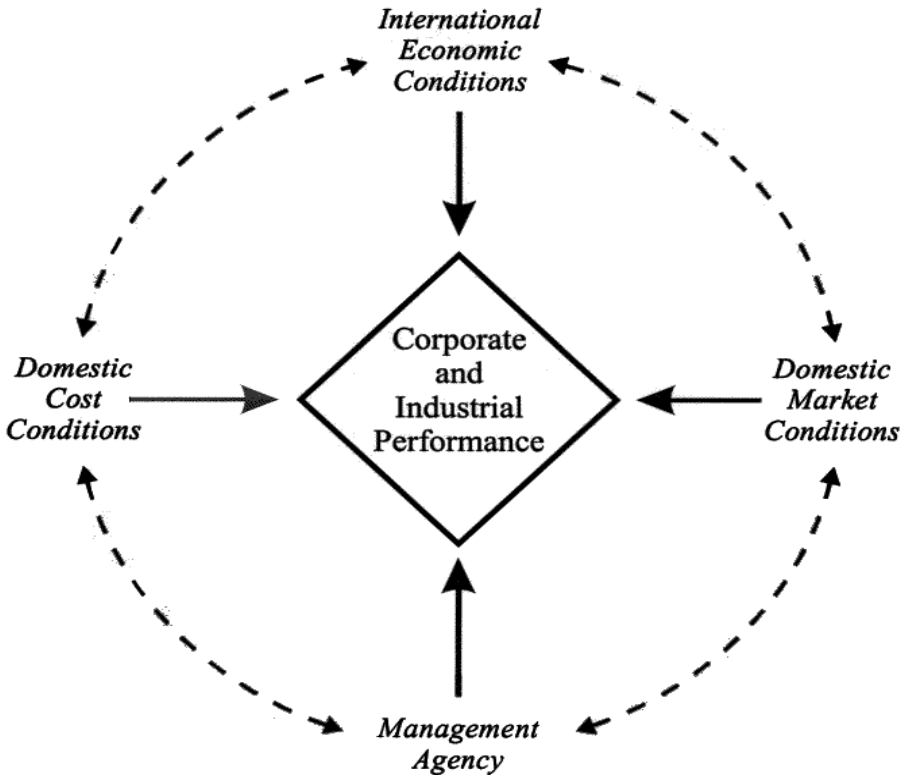
PROXIMATE CAUSES OF GROWTH AND DEVELOPMENT

In our view, the postwar growth and development of the Japanese electronics industry is best represented as the product of dynamic evolutionary forces, complexity and multi-causality matched by the existence over the years of a relatively small number of industry constants. On the one hand, complexity may be seen to have resulted from the interplay of macro and micro forces and domestic and international developments. On the other hand, the powerful upward trajectory of the industry over more than four decades, to become established at the forefront of the global industry, may be represented as the product of four mutually reinforcing forces, each of which has varied in intensity and importance from time to time. The four determinants of corporate and industrial performance and the manner of their interaction are presented in Figure 1.

The model, while abstracting from reality, has the virtue of demonstrating that electronics enterprises and management teams existed in a particular historical context, which *ipso facto* conditioned strategic choices. It has the further advantage of providing a scheme for the classification of the main factors governing the long-term performance of the industry. In all, twelve main factors may be identified as key proximate causes of growth and development.

FIGURE 1

THE JAPANESE ELECTRONICS INDUSTRY:
DETERMINANTS OF CORPORATE AND INDUSTRIAL PERFORMANCE



Domestic Cost Factors

- Japanese firms had the advantage down to the 1970s of relatively low wages and a low labour share of value added (Jaffar, 1998).1 This conferred the twin advantages of being able to manipulate prices competitively while yielding substantial retained earnings to fund large-scale investments.

- From the early 1950s onwards, Japanese firms benefited from having a highly disciplined and committed workforce, reluctant to jeopardize firms' wellbeing through strike action or to restrict output and productivity growth (Price, 1997, 270-73). The existence of a dedicated and responsive labour force allowed firms to take full advantage of innovations in methods and systems of production without conceding all the gains to labour in the form of higher wages and improved conditions of employment.

- High rates of corporate and individual savings created a situation of abundant capital at low cost, which in turn facilitated the pursuit of economies of scale and scope through massive investments in production, research and development (R&D), and marketing (Denison and Chung, 1976).

Domestic Market Factors

- The domestic market for electronic goods benefited from a high-income elasticity of demand for its products when for several decades the rate of growth of Japan's GNP considerably exceeded that of its main rivals (Argy and Stein, 1997).
- While the domestic markets for consumer and industrial electronics were buoyant, they were in part protected from foreign competition by the continuation of Japanese import restrictions. This meant that domestic prices could be kept high and that domestic sales alone could underwrite heavy investments in new product development, plant and equipment (Komiya and Itoh, 1988).

International Economic Factors

- The postwar international political settlement favoured Japan by giving ready access to overseas markets despite a lack of reciprocity. Hence the toleration displayed by western countries down to the 1980s of high and rising Japanese manufacturing trade surpluses (Steven, 1996).
- The significant undervaluation of the yen against the dollar during the era of fixed exchange rates gave Japanese electronics a big competitive advantage in overseas markets, stimulating the pursuit of high export ratios and scale economies (Shinohara, 1982.)
- Japan, before it was seen to be a major rival, was granted ready access to crucial western technologies (as well as management expertise) through licensing and other agreements. Without access to leading-edge technologies during the critical formative period of the modern electronics industry in the 1950s and 1960s, the Japanese electronics industry could not have embarked on the expansionist international path that it took (Imai, 1992).

Internal Firm Factors

- Industry leaders pursued a logic-of-action similar to that identified by Chandler in *Scale and Scope* (1990), recognizing at an early stage the need to make massive investments in production, distribution and management in order to compete successfully in international markets. The internalization of this view by management led firms continuously to upgrade their knowledge base, systems, processes, human resources, capital stock and product range.
- Control of key product and production technologies was seen at an early stage to be crucial to long-term success within the global electronics industry. Initially through licensing, but fairly soon thereafter through self-generated R&D, Japanese firms reaped the rewards of technological excellence (Harryson, 1998; Fruin, 1992; Fruin, 1997).
- High quality standards and responsiveness to customer needs were established as core industrial values during the postwar reconstruction period. The belief that the customer always has new needs, and that it is necessary for firms proactively to identify and satisfy these, has led to numerous product innovations and the securing of economies of scope in production and distribution (McMillan, 1985).
- Japanese managers within the electronics industry have responded with alacrity to fundamental shifts in competitive conditions. The massive transfer of production of consumer electronics from domestic to offshore locations is

but one of numerous examples of a deep-seated understanding that individual firms must work with and not against the logic of the market (Fujino, 1998).

The critical point to emerge from this taxonomy of the proximate sources of growth and development is that individual firms and business leaders were neither passive beneficiaries of uniquely favourable circumstances nor were they alone responsible for the success enjoyed by the Japanese electronics industry. What they must be credited with is discerning at critical moments what was required to take full advantage of new technologies and market opportunities and to act accordingly in making a long series of bold strategic investments. In practice, of course, it is not possible to isolate the impact of one factor or determinant from another, as the dashed lines in Figure 1 indicate. The situation is more akin to that described by Porter in *The Competitive Advantage of Nations* (1990), wherein mutually reinforcing interactions generate the momentum to create globally competitive industry clusters.

ULTIMATE CAUSES OF GROWTH AND DEVELOPMENT

Any search for the ultimate causes of corporate and industrial growth involves studying the motivation and behaviour of economic actors at the level of both the individual and the organization. Inevitably these are mediated at the societal level through more general economic, cultural and political processes. All events and outcomes are in this sense historically contingent. From this viewpoint, a business enterprise is conceived primarily as a community dedicated to the maintenance and development of a value creating system. The community is shaped and conditioned by environmental pressures and by the values and aspirations of its members, who in turn are influenced through their involvement with others in society. Corporate culture is defined as the shared values, beliefs and aspirations of members of the community, which find expression in the way they routinely behave and cooperate (or not) with others by way of formal and informal relationships (Lewis, Fitzgerald and Harvey, 1996, pp. 1-54). The answers to ultimate questions, such as how and why business enterprises at a particular point in history form an enduring social settlement (the division of value added between capital and labour), can only be found through the analysis of historical, political and cultural processes.

It is difficult now, more than half a century later, to comprehend the depth of despair felt in Japan at the dramatic conclusion of the Second World War. Hyperinflation, mass unemployment and occupation followed, and it was not until the early 1950s that the country could look forward once again to a brighter future (Tabb, 1995). The details of how the Japanese people came to terms with defeat and rebuilt their nation and its place in the international community are beyond the scope of this article. However, the argument presented here is fundamentally informed by our understanding of some of the most salient stylized facts of postwar Japanese history.

Occupation and Economic Reconstruction

In pursuing its twin political objectives of demilitarization and the establishment of democracy, the Occupation administration actively promoted the economic reconstruction of Japan between 1945 and 1952. Most conspicuously, steps were

taken to reform the old *zaibatsu* and the managerial class was purged of industrial leaders stained by association with militarism (Morikawa, 1995). More importantly, it is accepted that economic expansion was needed to legitimize the new democratic pro-American political order. The electronics industry was a natural candidate for assistance through the agency of its Civil Communications Section, which promoted schemes for technical assistance and the introduction of modern management techniques under the banner of the quality movement. These initiatives had long lasting effects, anticipating the high profile work of management gurus like Deming, Juran and Drucker, and were consolidated between 1955 and 1962 through the work of the US technical assistance programme. Influential agencies such as the Electronics Industry Association of Japan (1948) and the Japan Productivity Center (1954) had their origins in American quality, productivity and technology initiatives (Nakamura, 1995, pp. 150-55).

Japan and the International Economic Order

Japan suffered from a chronic balance of payments deficit for more that a decade after the end of the Second World War, notwithstanding the boost to exports resulting from the special procurements *(tokuju)* boom induced by the outbreak of the Korean war in June 1950. This was perceived in Washington as a fundamental threat to political and economic stability in Japan at a time when fear of communism was far from subsiding (Morishima, 1982, pp. 164-65). It is for this reason that the United States gave its blessing to the Foreign Exchange and Trade Control Law of 1949 and the Foreign Investments Law of 1950 that together provided a considerable degree of protection to nascent Japanese industries. Informal but effective protectionism was tolerated long after Japan had joined the IMF (International Monetary Fund) (1952) and had formally acceded to GATT (General Agreement on Tariffs and Trade) (1955). Even when the Japanese balance of payments swung into massive surplus, the infant industries having grown up, the United States government continued to look benignly on the situation: the political gains from stability in Japan were seen to outweigh the economic costs (Kosai, 1986). Against the prevailing economic logic, the yen remained pegged at 360 to the dollar down to 1971, yielding a massive cost advantage to Japanese exporters.2 Only after the Plaza Accord of 1985 was the situation fully normalized (Belberdos, 1997).

Reconciliation of Capital and Labour

The history of labour relations in Japan in the first decade after the war is one of searing conflict followed by healing compromise. Labour was very much in the ascendancy during the crisis-torn hyperinflationary years (1945-49) when Japan's political future hung in the balance. Management sought to reclaim lost ground over the next few years, asserting its right to manage, and dismissing large numbers of workers following a series of calamitous strikes. The damage wrought by management-union antagonism served as a potent reminder of the costs of conflict, and as the economy stabilized in the early 1950s both employers associations and unions began to see virtue in a more conciliatory approach to wage bargaining (Price, 1997; Gordon, 1988). The 'new deal' settlement, seen nowadays as a quintessential part of the Japanese system, was established during the 1950s as a consensus emerged that capital and labour should work together in pursuit of prosperity. Relative stability of employment was guaranteed in exchange for corporate loyalty and recognition of

the efficacy of mutual consultation. By the mid-1950s, the old politicized unions had given way to newer enterprise unions that stressed the unity of purpose binding the firm. There were two main consequences. First, the share of value added (sales minus purchases) distributed to labour in wages and salaries was much lower in Japan than in competitor nations. Correspondingly, a relatively high proportion of earnings was available for investment. Second, the 'new deal' social settlement prioritized long-term growth over short-term profit maximization in order to keep the workforce in continuous employment (Sugayama, 1995).

Corporate Governance and Business-State Relations

Before the Second World War, a lack of adequate market mechanisms caused firms in many sectors to internalize activities within conglomerate structures. At the heart of several *zaibatsu* was a large bank, while associated general trading companies, the *sogoshosha*, provided access to raw material and overseas markets. The *zaibatsu* were formally disbanded after 1945 as part of the demilitarization process, but the economic logic of cooperative alliances encouraged the same groups to re-coalesce as the *kigyo shudan* (enterprise groups). Mutual shareholdings created a fresh network of supportive strategic alliances, and company groups continued to facilitate investment and the flow of market intelligence in the reconstruction period and beyond (Suzuki, 1991). The ability of large corporations, the *kaisha*, to attract the support of banks, business allies and government facilitated rapid industrialization in postwar Japan (Abegglen and Stalk, 1985). Government, through the agency of the Ministry of International Trade and Industry (MITI) and other bodies, was able to exert strategic influence through a process of administrative guidance (*gyosei shido*), striking a balance between cooperation and competition (Fruin, 1992). The system served to highlight and define strategic issues and to target resources in a flexible and effective manner (Tidd, Bessant and Pavitt, 1997, pp. 85-87). This was a classic response to the problem of relative economic backwardness and the struggle to catch up with more advanced competitor nations. As the economy developed and companies upgraded their organizational capabilities, so they became progressively less in need of support from the banks and state agencies (McMillan, 1995; Johnson, 1982; Aoki, 1997; Scher, 1997; Johnstone; 1999; Lazonick, 1999).

Economies of Scale and Scope

In *Scale and Scope*, the classic study of the dynamics of industrial capitalism, Chandler (1990) makes the case that enterprises grow large and prosper when they remain focused and committed to the exploitation of economies of scale and scope. According to this view, large-scale investments are often needed in order to capture fully economies of scale in production, distribution and marketing, and to recoup R&D costs. Firms that exploit opportunities to win a significant market share through driving down unit prices while maintaining product quality secure sustainable first-mover advantages. These arise through reputation effects and because profits flow thick and fast for those that move first to capture scale economies. High profits mean that first-movers can reinvest heavily to keep ahead of the competition and diversify harmoniously to capture economies of scope (spreading R&D costs yet more thinly). Such firms enter a virtuous circle in which each sizeable new investment in physical, human and intellectual resources builds organizational capabilities and in turn the cash needed to sustain corporate growth and development. In confirming the

applicability of the Chandler model to postwar Japan, Morikawa has demonstrated how the managerial elite that rose to prominence after 1945 pursued this logic-of-action and gave immediate priority to capital investment and building organizational capabilities rather than short-term profit maximization. Investments in plant, equipment and distribution were made on an unprecedented scale. A virtuous circle ensued: 'increasing equipment investment led to market expansion, which generated new business opportunities, stimulated competition for market share, and encouraged further equipment expansion' (Morikawa, 1997, p. 321).

These stylized facts embrace many of the ultimate causes Japanese economic growth in the postwar period. Our list is not exhaustive nor is our account complete. But what we can say with confidence is that industrial success on the scale achieved was the product of a unique combination of historical circumstances. The Occupation administration strove for economic regeneration as a means of achieving political goals, and by the same token Japan was granted an advantageous position in the international economic order. High rates of corporate and personal savings, promoted by a social settlement between capital and labour that favoured accumulation over consumption, provided the means by which industrialists could take advantage of favourable domestic and international market conditions. The prevailing system of corporate governance, reinforced by supportive government agencies, encouraged a coordinated and strategically astute approach to corporate and industrial growth. Japan's new managerial class had a strong predilection for growth, investing heavily to secure economies of scale and scope, to win commanding market shares, and ultimately to build formidable organizational capabilities (Odagiri, 1992).

Each of these forces was at play in creating the technologically sophisticated Japanese electronics industry of today. Companies such as Hitachi, Mitsubishi Electrical, NCR Japan, NEC, Nippon Columbia, Pioneer, Sharp, SMK, Stanley Electric, Tamura, TDK, Matsushita and Toshiba survived the tribulations of the Second World War, but the transition from war to peace was initially a slow and demanding process. However, some bright spots did emerge at an early stage encouraged by government and the Occupation administration. By the late 1940s, for example, there were some 200 companies contesting radio receiver production. Indeed, radio manufacturing had almost regained its 1941 wartime peak by 1948, and production levels escalated from 287,000 sets in 1950 to 10.2 million sets in 1959. The record of monochrome TV production tells a similar story of year-on-year growth with the number of sets produced rising from just 14,384 in 1953 to 2,872,209 in 1959. From virtually a standing start in 1945-46, the industry was producing goods to the value of Y391.5m by 1960 and already 16 per cent of sales were made abroad (Bureau of Statistics, 1948-60).

It was after 1960, however, that the Japanese industry mounted a serious challenge to its American and European rivals in international markets. Output and exports forged ahead once firms had achieved mastery of solid-state technologies (Kimura, 1984). The figures presented in Tables 1 and 2 paint a remarkable picture. These suggest that the years between 1960 and 1995 may be divided into three periods. First, the period of super-fast growth between 1960 and the slowdown induced by the oil crisis of 1973. It is conspicuous that for electronics manufacturers at least, the oil crisis bit harder in domestic markets than it did internationally. Continued strong export growth buoyed up the industry such that growth rates remained positive even during the

darkest of times. Thus during the second period, from 1973 to 1985, high rates of growth in output were underpinned by the industry's strong performance in export markets. There is an evident change in pattern during the third period, the decade following the Plaza Accord of 1985 that was marked by the phenomenon of yen appreciation. As the yen climbed steeply in value against the US dollar, Japanese electronic products became steadily less competitive in export markets and there was a commensurate downward pressure on profit margins. Manufacturers responded by shipping production offshore to the low-wage developing economies of South East Asia and mainland China. Hence the sharp downturn in growth rates for output and exports, especially after 1990 when economic stagnation at home marked the end of the golden era of the Japanese electronics industry.

TABLE 1: Output and exports of the domestic Japanese electronics industry, 1960-95 (1990=100)

Year	Output		Exports	
	Current Prices	1990 Prices	Current Prices	1990 Prices
1960	1.6	1.2	0.6	0.4
1965	2.7	2.2	1.9	1.6
1970	12.2	10.3	7.2	6.1
1975	18.1	13.0	15.5	11.2
1980	36.1	26.3	38.5	28.1
1985	77.5	60.3	88.2	68.6
1990	100.0	100.0	100.0	100.0
1995	94.1	116.0	105.5	130.1

Sources: Computed from annual volumes of Bureau of Statistics, *Japan Statistical Yearbook*,
and annual volumes of Ministry of International Trade and Industry *Foreign Trade of Japan.*

TABLE 2: Average annual percentage rates of growth of Japanese electronics domestic output and exports, 1960-95

Year	Output		Exports	
	Current Prices	1990 Prices	Current Prices	1990 Prices
1960-65	10.6	15.5	26.2	29.3
1965-70	35.2	35.6	31.1	31.4
1970-75	8.3	4.8	16.6	12.8

1975-80	14.8	15.1	20.0	20.3
1980-85	16.5	18.1	18.0	19.6
1985-90	5.2	10.6	2.5	7.8
1990-95	-1.2	3.0	1.1	5.4

Sources: Computed from annual volumes of Bureau of Statistics, *Japan Statistical Yearbook*,
and annual volumes of Ministry of International Trade and Industry *Foreign Trade of Japan.*

FROM KNOWLEDGE DEPENDENCE TO KNOWLEDGE CREATION

The powerful upward movement in production and exports recorded by the Japanese electronics industry over successive decades may give the impression of a simple yet compelling logic at work. But nothing could be further from the truth. Sustained growth over a long period was, in this instance, more the manifestation of effective structural change and adaptability than the persistent exploitation on a global scale of a limited number of markets. In fact, the industry displayed a remarkable capacity to re-invent itself in the face of cost and market imperatives. There have been profound changes in the balance of production within the domestic industry. In 1960, the industry was primarily identified with the production of consumer goods such as radios and televisions; by 1995 the situation was almost completely transformed. The long-term thrust recorded in Table 3 has been to foster the production of high value-added industrial equipment and electronic components. Meanwhile, the assembly of consumer products has been moved to lower wage economies offshore, especially after 1985 (Jaffar, 1998). Hence the sudden surge in components as a proportion of exports after that date.

TABLE 3: Sectoral shares of domestic output and exports of the Japanese electronics industry, 1960-95 (percentages)

Year	Output			Exports		
	Consumer	Industrial	Components	Consumer	Industrial	Components
1960	57	11	32	na	na	na
1965	51	22	27	na	na	na
1970	49	28	23	na	na	na
1975	36	38	26	51	25	24
1980	34	35	31	48	20	32
1985	26	41	33	39	30	31
1990	18	47	35	24	31	35
1995	11	47	42	11	26	63

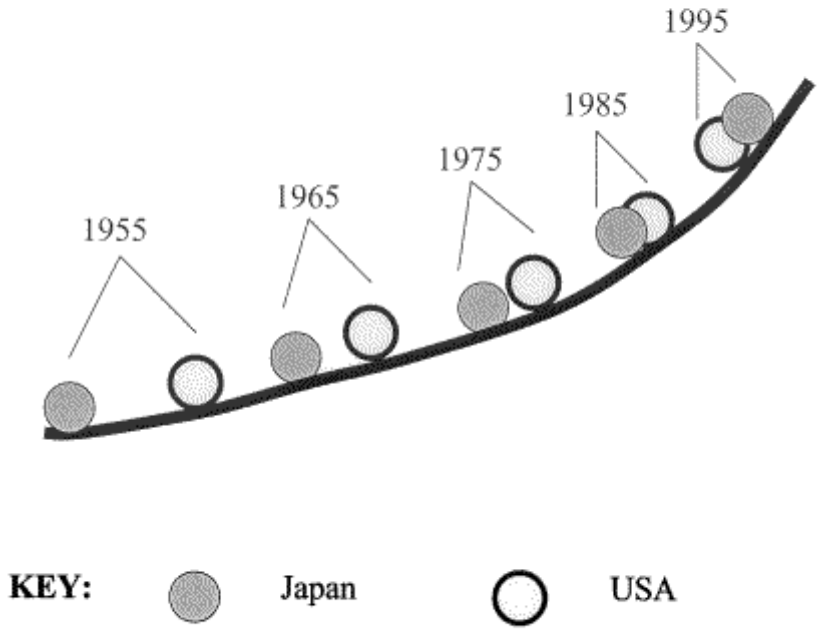
Sources: Computed from annual volumes of Bureau of Statistics, *Japan Statistical Yearbook*,
and annual volumes of Ministry of International Trade and Industry *Foreign Trade of Japan.*

Fundamental to the process of long-term structural change within the industry was the increasing mastery of Japanese firms of relevant technologies and scientific knowledge, without which it would have been impossible to progress from a position of knowledge dependency to one of knowledge creation. The ability to acquire, control, utilize and commodify technological knowledge became assimilated over time as one of the core competencies of individual firms and the industry as a whole. This development has been depicted elsewhere as a series of distinct stages. Westney (1994), for example, identifies the 1950s and 1960s with technology imports, the 1970s with improvements in production technologies and quality, and the 1980s with domestically generated technologies and basic research. In our view, any such view is fundamentally flawed and misleading: both the nature of the process at work and the available empirical evidence defy such ready classification. At the level of the industry as a whole, the transformation process was progressive and more akin to continuous improvement than a series of staged paradigm shifts.

This view is implicit in the 'mountain climbing' metaphor of the technological advance of the Japanese electronics industry put forward by Makoto Kikuchi (1989), one-time Managing Director of Sony's corporate research centre. A modified and updated Kikuchi 'model' is presented in Figure 2.

FIGURE 2

THE 'MOUNTAIN CLIMBING' METAPHOR OF TECHNOLOGICAL PROGRESS WITHIN THE NON-MILITARY JAPANESE ELECTRONICS INDUSTRY



Source: Adapted from an original idea by Makota Kikuchi (one-time Managing Director of the Sony Research Center)

The 'model', though highly subjective, is useful in drawing attention to a number of important points. First, the US electronics industry throughout the postwar period served as the technological exemplar for Japan: it is in the US that standards traditionally have been set and key technologies developed, refined and commercialized, establishing the benchmarks against which Japanese firms have measured their success in closing the 'technology gap' (Oshima, 1987). Second, both the US and the Japanese industries have lived through a protracted period of technological development, distinguished by intensive organizational learning and the creation of fresh technological capabilities ('climbing the mountain')(Odagiri and Goto, 1996). Third, for a long period, down to the mid-1980s and the triumph of very large scale integration (VLSI), the Japanese industry was on balance playing 'catch-up' with the American industry. Fourth, the process of technological change, involving as it has done very large numbers of products and processes, in aggregate has been incremental rather than involving sudden shifts or movements. The pattern is one of progressively rising technological complexity, interdependence and sophistication (Kodama, 1991). Fifth, Japanese firms have moved forward from a low base more rapidly than their US rivals, taking the lead in many fields (liquid crystal displays, flash memories and professional broadcasting equipment, for example), to achieve an overall position of technological leadership within the non-military world industry.

The ultimate causes of the technological advance of the postwar Japanese electronics industry, moving from knowledge dependence to knowledge creation, are intimately bound up with the business history of modern Japan. Modern economic growth began following the Meiji restoration in 1868 and the exposure of the country to foreign ideas and influences. Mechanisms were developed, in part unique to Japan, which compensated for the lack of efficient markets and widespread manufacturing know-how. The state and its allies in business drove forward a modernizing agenda that in the 1930s became distorted by militarisation and imperial ambitions. Notwithstanding, managerial and technological skills were accumulated and these were deployed to the full in the service of the military during the Second World War (Okazaki, 1994). Japan's economic heroes, like their military colleagues, were humbled by defeat. Between 1945 and 1947 the Occupation administration actively remodeled business enterprises, government and university departments along civilian lines, terminating all activities that might serve military ends (Nakayama, 1991). Numerous engineers and scientists joined the ranks of the unemployed.

Yet, whatever the immediate problems of adjusting from war to peace, Japan, like Germany, emerged from the war with a worthy industrial legacy in the form of established 'high technology' companies, business managers and engineering talent (Fransman, 1990, p. 13).3 The main economic problems faced by Japan in 1945 were macroeconomic, political and structural, not corporate *per se*, although there were serious adverse consequences for business resulting from inflation, low levels of effective demand and a strident labour movement. Once these problems were resolved, however, Japanese electronics firms were well placed to confront the problem of relative technological backwardness that had existed before the war but which had been exacerbated by it. Furthermore, after 1947 and the issue of the Truman doctrine, the US government turned from foe to friend in actively promoting the transfer of technology and manufacturing know-how from the US to Japan (Hayashi, 1990). Military applications of American technology may have been banned, but this only served to concentrate resources and speed the rate of effective technology transfer.

Technology transfer was one element of a national strategy for the industrial recovery of Japan. Relative economic backwardness and a lack of natural resources suggested export-oriented industrialization as the natural development path. If the country was to pursue this course successfully Japanese goods had to compete in international markets on the basis of both price and quality. This in turn required the importation of western technology and manufacturing know-how. The problem that confronted the Occupation administration and the government was how to pay for technology and capital equipment imports at a time when Japanese manufactures were uncompetitive in international markets.

The solution lay in the adoption of a distinctly nationalistic and quasi-protectionist set of economic policies and administrative procedures (Nester, 1991; Shin, 1996). In this way, domestic markets were protected from competition, and the foreign exchange released for technology and capital imports was targeted at improving the productivity and productive potential of industries with good export potential. The two main legislative instruments regulating technology imports were the Foreign Exchange and Foreign Trade Control Law (FEFTCL) of 1949 and the Foreign Investments Law of 1950. Under these laws, technology agreements were only 'validated' once signed off

to the satisfaction of the Bank of Japan, the Ministry of Finance, MITI and the Science and Technology Agency (Kosai, 1986, p.55). The guiding principle according to a team of British businessmen visiting Japan in 1962 was that agreements should contribute to 'the self-support and sound development of the Japanese economy' and 'the improvement of the international balance of payments.' The system allowed MITI to achieve a high degree of administrative coordination in trying and testing technologies before approving their adoption on an industry-wide basis. In a typical year during the 1950s more than 100 agreements were signed granting access to foreign technology and patents in exchange for royalty payments of approximately 3 per cent for technology, 5 per cent for patents and 7 per cent for technology plus patents. By 1961 the cost of technology imports had risen to $111 million (EPA, 1962, p. 59).

Japanese electronic firms, staffed by experienced engineers and scientists, had the absorptive capacity to make the most of foreign technology imported at what would prove to be bargain prices. Sony, for instance, gained access to transistor technology in 1953 through its patent contract with Western Electric, and by 1957 had launched the world's first transistor radio. It proved a resounding success in both the domestic and export markets. The Japanese had recognized the strategic importance of transistorized solid state technology and by 1960 the vacuum tube was effectively obsolete (Odagiri and Goto, 1996). What made the transistor revolution particularly significant was that it gave manufacturers the opportunity to miniaturize components and end products, saving on both energy and materials. By the late 1960s, the basic transistor itself had been superseded by the more advanced integrated circuit, which led to major savings through process simplification reduced power consumption. The new industrial field of semiconductor manufacturing was thereby brought into being in Japan. A remarkable amount of technological knowledge flowed into the country during the 1950s and 1960s, representing a striking example of both tacit and explicit knowledge conversions on an industry-wide scale (Nonaka and Takeuchi, 1995).

Integral to the process of technological absorption was the introduction and refinement of new manufacturing methods. As with fundamental technologies, however, the majority of these methods originated in the US. It was in the 1940s and early 1950s that Japanese electronics firms made their commitment to quality as a guiding principle. The lead was taken by the Civil Communications Section (CCS) of the Occupation administration, whose course on modern management methods ran for the first time for two six-week periods in 1949 and 1950.[4] The course stressed the importance of engaging employees in the planning process and aligning their aspirations with long-run organizational goals. A key message was that the customer should define quality, while a lack of commitment to quality equated to an indifferent corporate strategy. Particular emphasis was placed on the role of middle managers as change agents, especially technologists and engineers who were encouraged to aspire to senior managerial positions. The graduates of the pioneering CCS course were active in later years in spreading the influential techniques and messages of American management gurus like Deming, Juran and Drucker. A further important source of ideas was the American technical assistance programme to Japan that ran between 1955 and 1962 at a cost of $12 million. The programme took 3,568 individuals in 345 teams from Japan to study business methods in the US. More than 100 American management consultants and engineers crossed the Pacific to spread the gospel of productivity and quality within large Japanese firms. At the same time, the Japan

Productivity Council was formed to disseminate information on modern management methods throughout Japanese industry. Tiratsoo (2000) argues that the technical assistance programme, though long overlooked in the management literature, had a profound impact 'in relation to specific techniques and processes, especially those intrinsic to the discipline of industrial engineering … at the very heart of efficient manufacturing.'

The fusion of technological and manufacturing expertise that resulted from (politically inspired) initiatives taken during the reconstruction era had emerged by the 1960s as a defining feature of the Japanese electronics industry. It made possible the rapid commercial deployment of technologies by reducing the lead-time between R&D and the launch of products with mass market potential (Fruin, 1995). Radios, monochrome televisions and colour televisions in turn became hit products at home and abroad, and the dawning of the television age swiftly suggested other possibilities. Initially, broadcasting studios were largely American-equipped, but by 1954 Ikegami Tsushinki (1992) had signed technical agreements with RCA and EMI, and within four years was producing its own transmission equipment. This was followed during the 1960s, again using US technology, acquired through collaboration with Ampex, by fully transistorized professional broadcasting equipment (VTRs). Within two years of the sale of the first two VTRs in Japan, both Sony and Toshiba had constructed their own prototypes, to be followed by similar versions from other manufacturers. The experience gained in this way, combined with the mastery of miniaturization, is fundamental to any explanation of Japan's command of the world VTR market by the end of the 1970s (Harryson, 1998, pp. 126-49).

Mastery of the art of conceiving and manufacturing high quality products at low cost that appealed to consumers and industrial customers in markets across the world triggered the virtuous circle of growth that saw the Japanese electronics industry go from strength to strength down to the 1990s. Market domination yielded strong cash flows, and because employees and shareholders were modest in their demands, there were exceptional amounts of free cash available for investment. This was targeted at product development, the acquisition and discovery of technological knowledge, investment in new plant and equipment, manufacturing and marketing systems development, and raising the productivity of employees through education and training. Multiple advantages accrued: notably, higher productivity, reduced unit costs, improved quality, more attractive and higher performing products, and short development times. All this worked to consolidate the position of Japanese firms within existing markets and to cultivate and command fresh markets. The sheer dynamic force of the process made for high and sustained rates of industrial growth (Teece, Pisano, and Shuen, 1997). Meanwhile, the prospective threats to the system that loomed large from time to time did not materialize. Nations disillusioned by Japanese trading practices felt unable to retaliate or were assuaged when Japanese firms made sizeable direct investments in the US and Europe (Belberdos, 1997; Kimura, 1994). Employees remained compliant and kept faith with a system that delivered security and steadily rising incomes. Shareholders had little to reason to complain about low dividends when the value of their holdings seemed to move forever upwards. Only with the bursting of the bubble economy in 1990 was the Japanese system of corporate governance seriously called into question (Lazonick, 1999; Dore, 1997; Bostock and Stoney, 1997).

The possession of a regular and lavish supply of investment funds enabled Japanese electronics firms progressively to enhance their technological capabilities (Vestal, 1993). This was done in two distinct but complementary ways. The first was to invest in people and the development of an innovation-minded corporate community. At the heart of this community were university-educated engineers and scientists. In the 1940s and 1950s these people were in short supply, and in 1959 Japanese electronics firms had only half the number per thousand employees as their US rivals (31 compared to 60) (Freeman, 1987, p. 10). Engineers and scientists were a scarce resource and this fact had an important conditioning effect on national, corporate and functional business strategies. At the national level, the knowledge sharing initiatives supported and guided by MITI were intended to get the most out of a relatively small engineering and scientific workforce. At the corporate level, every effort was made to lure individuals away from universities and other competing employers through the provision of excellent facilities and conditions of employment. Companies offered continuous employment, good rewards and high professional status, and opportunities for personal development at home and in the US as inducements to join their 'family' (Itoh, 1994). At the functional level, engineers and scientists had of necessity to be 'spread' across the organization, moving periodically between central laboratories and divisions, between R&D and production, and between specific projects and regular operations. They also had need to relate closely to shop-floor workers and to draw upon them for ideas and support (Schroeder and Robinson, 1993). Flexibility and cooperative working were thus born out of necessity.

In our view, three of the defining elements of the Japanese approach to technology acquisition and management were in origin a product of relative economic backwardness. When the electronics industry began to power upward towards the end of the 1950s and when large amounts of free cash became available, familiar norms, standards and methods of working had already been established throughout the electronics industry. These are manifest in what Lazonick and West define as 'organizational integration' (Lazonick and West, 1998). Japanese capitalism is portrayed by them as 'collective', characterized by highly relational communities that extend beyond the boundaries of individual firms, universities or public bodies. Under these social arrangements 'know-who' is as important as 'know-how' and innovation is frequently the product of multi-disciplinary project teams. R&D and manufacturing are linked through the collective knowledge of engineers and scientists and a common sense of organizational purpose. Ideas are drawn from multiple sources from within and outside firms and they are developed collectively through the vehicle of the project team (Imai and Clark, 1994). Stability and continuity result from the fact that senior technologists remain with the same firm rather that moving periodically to advance their careers as in the US. All this continues to apply even though the initial problem of a lack of graduate engineers and scientists has long since disappeared. Already by the end of the 1970s the number of people graduating from university with first and higher degrees in electrical and electronic engineering was higher in Japan than in the United States (21,435 against 16,093 in 1979) (Freeman, 1987, p.47). Moreover, with 80 per cent of R&D concentrated in private firms and directed at civilian ends, Japanese electronics enterprises had moved from a position of critical human resource scarcity to one of abundance (Freeman, 1987, p. 11).

The second means of enhancing technological capabilities was through the creation and regular enhancement of R&D facilities, systems and routines. Okimoto and Nishi

(1994) have provided a stylized description of the pyramidal research infrastructure of the large integrated semiconductor manufacturers, and the same description might be applied to the integrated electronics majors. A Central Research Laboratory (CRL) forms the apex, Divisional Laboratories (DLs) occupy the middle levels, and a multiplicity of Factory Engineering Laboratories (FELs) forms the baseline. The CRL, operating on a five to ten year timescale, is responsible for nurturing and expanding the fundamental and theoretical technological knowledge of the firm. The DLs are engaged in product development. Interactions with the CRL are two-way: at times they respond to product ideas pushed downwards, at other times they commission fundamental research. The FELs take responsibility for the implementation and refinement of manufacturing processes working in close conjunction with relevant DLs and on occasion with central manufacturing process teams. The pyramidal model had its origins in American industry and dates back to the early 1900s. Japanese firms from the late 1950s emulated it: many of the largest CRLs of today (Sony, for example) date from the early 1960s (Nakayama, 1991, pp. 97-102).

In moving from knowledge dependence to knowledge creation, it is not structures and systems *per se* that have served the Japanese electronics industry so well: it is the way in which they have functioned at a human level and have constantly adapted to environmental changes and competitive pressures (Fransman, 1995). The case of Sharp is illustrative.5 In 1970, Sharp began to develop a new CRL, its Advanced Development and Planning Centre, on a 55-acre greenfield site. The complex took ten years to complete at a cost of Y7.5bn, a sum equivalent to 70 per cent of the company's capitalisation in 1980. The Sharp CRL consists of numerous fundamental R&D groups. Research is commissioned by DLs responsible for product development. Primacy rests at the DL level because it is the divisions that are best placed to anticipate customer requirements. A Production Technology Group is responsible for ensuring on an interactive call and response basis the transfer of technology between corporate R&D and manufacturing. Research and engineering personnel work across the system and are often conscripted to project teams to research a new technology or develop a new product or solve a manufacturing problem. The unifying strategic idea is that of the base technology. Starting from a single base technology (or core component) as many commercial applications as possible are developed (this is known as the 'spiral system'). For example, on the basis of its command of liquid crystal technology Sharp has 'spiraled out' numerous devices in the fields of home appliances, electronic advertisements, AV equipment, games consoles, medical electronics, industrial sensors, automotive devices, computer screens and many others.

Many Japanese electronics firms have followed a similar path to that of Sharp (Fruin, 1997; Collinson and Molina, 1995; Harryson, 1998). The overall thrust has been to evolve, step-by-step from the disjointed and resource deficient organizations of the 1950s to the highly integrated and well-resourced organizations of today (Sigurdson, 1995). In the immediate postwar decade, Japanese firms lacked the know-how and systems needed to bring homegrown inventions like the Esaki diode (1957) to commercial fruition. But this situation did not last long. By the 1960s, many firms had the capacity to absorb and make the most of imported technologies. As the industry boomed, the demand for technology from overseas grew rather than receded as the absorptive capacity of firms increased. At the same time, Japanese firms began to

invest heavily in more fundamental research, creating an indigenous capability to generate and exploit original ideas. This was signaled by a steep rise in patents issued to Japanese inventors at home and abroad (from 8.9 to 17.9 per cent of all US patents issued between 1975 and 1985) (Freeman,1987, p.21). By the early 1980s it was evident that in non-military electronics Japan had virtually closed the technology gap with the US. The Japanese triumph in VLSI, which saw its manufacturers claim 48 per cent of the world semiconductor market in 1987 (compared to 39 per cent for the US), marked a watershed (Forester, 1993, p. 45). Thereafter it was no longer possible simply to dismiss Japanese firms as technological followers riding on the back of pioneering US corporations: the one-time follower had plainly emerged as a technological leader.

CONCLUSION: INTERPRETATION, OUTCOMES AND IMPLICATIONS

The thrust of the argument put forward in this article is that the technological advance of the Japanese electronics industry (1945-95) was in essence a *product not a primary cause* of industrial growth. We have demonstrated that the industry's surge forward resulted from the interaction of a unique combination of political, economic and cultural forces. Business leaders took full advantage by investing on a massive scale in physical, organizational, human and technological resources. It was success in the marketplace and strong cash flows that allowed Japanese firms to import technology on a large scale, invest in scientists and engineers, and progressively develop world class technological capabilities. This is not to say that technological progress was not essential to industrial growth. Plainly it was. But the movement from knowledge dependence to knowledge creation ultimately followed in the wake of business expansion: technology, down to the 1980s, was a lagging rather than a leading variable in a dynamic process of systemic growth.

Interpretation Three related theoretical ideas are helpful to a general understanding of the postwar growth and technological advance of the Japanese electronics industry. The first is that of *relative economic backwardness.* According to Gerschenkron (1962), a moderately backward industrializing nation such as Japan in the late 1940s and 1950s would, with strategic guidance from the state and big business, focus its efforts on modernization in a limited number of industries. In such countries, market mechanisms are imperfect and the resources needed for development are in short supply; hence the drive to concentrate resources and the concomitant internalization of market functions by firms. Corporate and industrial leaders in effect find substitutes for mechanisms and resources that are more readily available in advanced economies. In the case of Japanese electronics, one of the main prerequisites for growth was the acquisition, absorption and deployment of western technologies. The main constraints were financial and human. Industry-wide sharing of (costly) knowledge through MITI and trade associations, the concentration of (scarce) engineering and scientific talent in private sector enterprises and rotational methods of deploying technologists, may be seen as strategic responses to the exigencies of moderate economic backwardness.

The important point is that economic backwardness fundamentally conditioned the development of the Japanese electronics industry. In terms of our second theoretical idea, its pattern of growth was *path dependent*: heavily influenced by systems, routines and norms established at an early stage (Mueller, 1997). Administrative

coordination through MITI and trade associations proved to be efficacious in the diffusion of technology and management techniques. Likewise, the concentration of R&D in private sector firms soon became structurally embedded. Meanwhile, at the operational level, many of the working practices that were born of necessity, such as the rotation of technologists and the extensive use of project teams, were culturally and systemically assimilated. History casts a long shadow.

We argue that the movement from knowledge dependence to knowledge creation was gradual, and resist the idea of staged paradigmatic shifts. The construct that best embraces our view of the change process is Lazonick and West's *organizational integration hypothesis* (Lazonick and West, 1998), the third of our key theoretical ideas. In the Gerschenkron model, economic backwardness is equated with variability, disjointedness and a lack of integration at the corporate, industrial and national levels. These were certainly features of the Japanese electronics industry immediately after the war. The trajectory was towards the integration of structures, systems and processes in the quest for higher levels of organizational effectiveness and efficiency. Integration extended beyond individual firms backward to suppliers and forward to customers. Conventional distinctions between R&D and manufacturing became blurred (Imai and Clark, 1994). Thus, while path dependency may impose constraints, it simultaneously embraces beneficial tendencies. In Japan, the tendency was towards organizational integration and the creation of deep-seated organizational and technological capabilities. Japanese electronics firms were thereby able to progress more rapidly than their American rivals, eventually emerging at the forefront of the non-military world electronics industry.

Outcomes and Implications

Fransman, in analyzing the characteristics of the Japanese 'technology-creating system', draws attention, as we have done, to the importance of history in fashioning its development. In his view, the crucial role played by MITI and state-funded laboratories was in reducing levels of uncertainty in private firms with regard to investment in R&D. By identifying and part-funding future-oriented research programmes, especially in industrial electronics, creative partnerships were formed and leading-edge technological knowledge disseminated throughout the industry. Economies of scale and scope in R&D were secured in the process. In this way, the state was able to lend strategic direction to the industry without destroying the benefits of competition between firms in various application domains. The industry was thus able to move successfully, as the technology gap between the US and Japan was closed, from the development of 'technology for tomorrow' to the creation of 'technology for the day after tomorrow.'

This aspect of the transition from knowledge dependence to knowledge creation is consistent with the thesis presented in this article. Japanese firms, when confronted by the problems resulting from economic backwardness, needed support and direction from the state in order to compensate for the high incidence of 'market failure'. The internalization of activities and routines was a second consequence, contributing to the creation of a distinctive system of corporate governance. Electronics enterprises became highly vertically integrated and affiliated in family groups. The dominant firms at the hub of the Japanese industry were resistant to voluntary collaboration in R&D because, as Fransman points out (1990, pp. 266-76), the transaction costs of

policing agreements were too high. Only with state aid could transaction costs be reduced to an acceptable level. When seen in this light, the technological history of the Japanese electronics industry is Janus-faced: at once a united national endeavour and a struggle between individual firms for the control of key technologies.

What is true today was just as true in the immediate postwar years. The corporate struggle focused then on the race to acquire foreign technology, with MITI and other government agencies mediating in pursuit of the collective good. Long after Japanese firms had begun to make independent technological advances, they continued to import far more technology than they exported.6 But the persistence of a negative balance of trade in technology, far from being a sign of continued backwardness, was a reflection of a deliberate strategy: the big players in the industry sought to extract the best technology they could from the rest of the world while limiting access to that which was 'made in Japan'. This is entirely consistent with the policy of 'internalize and control' that has long been a defining feature of the industry. The current technology policies of Japanese firms bear testimony to the enduring nature of this characteristic logic-of-action (Ordover, 1991; Okada and Asaba, 1997). Within Japan, electronics firms occupied second, third, fourth, fifth, seventh and ninth positions in the national R&D expenditure league table in 1996. Outside Japan, they have become senior partners in numerous global R&D networks, embracing private sector firms and top research universities (Cairncross, 1994; Turner, Ray and Hayward, 1997). There is nothing fanciful about such collaborations: the aim, as ever, is to gain control over scientific and engineering knowledge that can be integrated within the technology-creating systems of Japanese firms (Teramoto, Richter, Iwasaki, Takai and Wakuta, 1994). What is certain is that Japan has learned the lesson of its own history: its intellectual property will never be so freely dissipated as that of the US when it was the undisputed leader of world electronics industry.

Notes

1. A recent study of the financial structures of Japanese electronic and computer manufacturers estimates labour's share of valued added at 44% in 1983 compared to 57% ten years later. Comparable figures are not available for earlier years, but it is nonetheless plain that well before the mid-1980s Japanese electronics manufacturers had very large amounts of cash available for reinvestment. (Jaffar, 1998).

2. On 15 August 1971, after repeated efforts to persuade Japan seriously to contemplate policies aimed at reducing a worsening US balance of payments situation, President Nixon unilaterally announced a temporary surcharge of 10% on imports. Under the terms of the subsequent Smithsonian Agreement of 18 December 1971, the surcharge was scrapped and a realignment of the major exchange rate parities was inaugurated, in effect paving the way for an era of floating currencies.

3. A point made by Fransman (1990, p. 13): 'The rapidity with which transistor and computer technologies were acquired from the United States and Europe and reproduced in Japan was largely a function of the substantial capabilities that had been built up in the country since the 1920s … Although the technological capabilities of these industries still lagged behind those of the world's leaders by the 1950s, enough had been learned to facilitate a fast and successful assimilation of the cluster of new technologies that heralded the arrival of the information age.'

4. In researching the activities of the CCS, we had the benefit of an extended interview with one of its leading lights, Homer Sarasohn, conducted in London by Tony Hayward on 13 December 1995. Matsushita reprinted the CCS course textbook in 1995 under the title Management Manual. Further reflections on the CCS and the origins of the quality movement in Japan derive from Y. Kondo, 'The Japanese Experience of Quality in the Last Half Century,' presentation in London 13 December 1995. Professor Kondo is a winner of the Deming Prize and since 1970 he has been a council member of the Union of Japanese Scientists and Engineers (more familiarly known as JUSE).

5. Tony Hayward compiled the case study material on Sharp. This consists of in-house documents on technology development and management, field notes and interview transcripts. Interviews were held with R & D personnel at the Tenri and Makuhari research facilities in May 1997. A further interview was conducted in Oxford with Dr Clive Bradley, then managing director of Sharp Laboratories Europe, in November 1996.

6. Interestingly, although Japan's overall technology trade (import and export of patents, designs, technology transfers, trademarks and software licenses) with the rest of the world was broadly in balance by 1990, the balance of trade with the US is still overwhelmingly in America's favour, which is significant as the US accounts for about 30% of Japan's technology exports and 70% of imports. In 1996, the deficit with the US stood at Y120bn. It ought, however, to be noted that the gap has been closing significantly during the 1990s. (Agency of Industrial Science and Technology, 1998, 48-57).

References

Abegglen, J. and G. Stalk (1985), Kaisha, The Japanese Corporation. Basic Books: New York.

Agency of Industrial Science and Technology (1998), Trends in Principal Indicators of Research and Development Activities in Japan. Tokyo.

Aoki M. (1997), 'Unintended Fit: Organizational Evolution and Government Design of Institution in Japan,' in Aoki M., H-K. Kim and M. Okuno-Fujiwara (eds), The Role of Government in East Asian Economic Development. Clarendon Press: Oxford.

Argy V. and L. Stein (1997), The Japanese Economy. Macmillan: Basingstoke.

Belberdos, R. (1997), Japanese Electronics Multinationals and Strategic Trade Policies, Clarendon Press: Oxford.

Bostock R. and C. Stoney (1997), 'Japanese Corporate Governance: Governance for the Twenty-First Century or a Model in Decline?,' Asia Pacific Business Review, 4, 63-82.

Bureau of Statistics (annual volumes, 1948-60), Office of the Prime Minister, Japan Statistical Yearbook. Tokyo.

Cairncross D., 'The Strategic Role of Japanese R&D Centres in the UK,' in Campbell N. and F. Burton (1994), Japanese Multinationals: Strategies and Management in the Global Kaisha. Routledge: London.

Chandler A.D. (1990), Scale and Scope: The Dynamics of Industrial Capitalism. Harvard University Press: Cambridge, Mass.

Collinson, S. and A. Molina (1995), Reorganising for Knowledge Integration and Constituency Building in the Age of Multimedia: Product Development at Philips and Sony (JETS paper no. 12): University of Edinburgh: Edinburgh.

Denison E.F. and W.K. Chung (1976) How Japan's Economy Grew So Fast: The Sources of Postwar Expansion. The Brookings Institute: Washington DC.

Dore R.P. (1997), 'The Asian Form of Capitalism,' in Admiraal P.H. (ed), The Corporate Triangle: The Structure and Performance of Corporate Systems in the Global Economy. Blackwell: Oxford.

EPA (Economic Planning Agency) (1962), Economic Survey of Japan. Tokyo.

EIAJ (Electronics Industries Association of Japan) (1993), Facts and Figures. Tokyo.

Forester T. (1993), Silicon Samurai: How Japan Conquered the World's IT Industry. Blackwell: Oxford.

Fransman M. (1990), The Market and Beyond: Information Technology in Japan. Cambridge University Press: Cambridge.

Fransman, M. (1995), Japan's Computer and Communications Industry: The Evolution of Global Giants and Global Competitiveness. Oxford University Press: Oxford.

Fruin W.M. (1992), The Japanese Enterprise System: Competitive Strategies and Cooperative Structures. Oxford University Press: Oxford.

Fruin W.M. (1995), 'Competing in the Old-Fashioned Way: Localising and Integrating Knowledge Resources in Fast-to-Market Competition,' in Liker J.K., J. Ettlie and J.C. Campbell (eds), Engineered in Japan: Japanese Technology Practices. Oxford University Press.

Fruin W.M. (1997), Knowledge Works: Managing Intellectual Capital at Toshiba. Oxford University Press: Oxford.

Fujino T. (1998), Globalisation and Consolidated Management. Bunshindo: Tokyo.

Gerschenkron A. (1962), Economic Backwardness in Historical Perspective. Harvard University Press: Cambridge, Mass.

Gordon A. (1988), The Evolution of Labor Relations in Japan: Heavy Industries, 1853-1955. Harvard University Press: Cambridge, Mass.

Harryson S. (1998), Japanese Technology and Innovation Management. Edward Elgar: Cheltenham.

Hayashi T. (1990), The Japanese Experience in Technology: From Transfer to Self-Reliance. United Nations: Tokyo.

Ikegami Tsushinki Co. Ltd, (1992), Company Profile. Tokyo.

Imai K. (1992), 'The Japanese Pattern of Innovation and its Evolution,' in Rosenberg N., R. Landau and D.C. Mowery (eds), Technology and the Wealth of Nations. Stanford University Press: Stanford.

Imai K. (1993), 'Globalization and Cross-Border Networks in Japanese Firms,' in Anderson, T. (ed), Japan: A European Perspective, Macmillan: Basingstoke.

Imai, K. and Clark K.B. (1994), 'Integration and Dynamic Capability: Evidence from Product Development and Mainframe Computers,' Industrial and Corporate Change, 3, 557-605.

Itoh H. (1994), 'Japanese Human Resource Management from the Viewpoint of Incentive Theory,' in Aoki M. and R.P. Dore (eds), The Japanese Firm: Sources of Competitive Advantage. Oxford University Press: Oxford.

Johnson C. (1982), MITI and the Japanese Miracle. Stanford University Press: Stanford.

Johnstone B. (1999), We were Burning: Japanese Entrepreneurs and the Forging of the Electronic Age. Basic Books: New York.

Kikuchi M. (1989), 'Cooperation of Industry in Japan with Higher Education,' in Phillips G.O., Innovation and Technology Transfer in Japan and Europe. Routledge: London

. Kimura Y. (1984), The Japanese Semiconductor Industry: Structure, Competitive Strategies and Performance. Greenwood Press: Greenwich, Conn.

Kimura Y. (1994), 'Japanese Direct Investment in the European Semiconductor Industry,' in Mason N. and D. Encarnation (eds), Does Ownership Matter? Japanese Multinationals in Europe. Oxford University Press: Oxford.

Kodama F. (1991), Analyzing Japanese High Technologies: The Techno Paradigm Shift. Pinter: London.

Komiya R. and M. Itoh (1988), 'International Trade and Industrial Policy,' in Inoguchi T. and D.I. Okimoto (eds), The Political Economy of Japan: Vol. 2 The Changing International Context, Stanford University Press: Stanford.

Kosai Y. (1986), The Era of High-speed Growth: Notes on the Postwar Japanese Economy. University of Tokyo Press: Tokyo.

Lazonick W. and J. West (1998), 'Organizational Integration and Competitive Advantage: Explaining Strategy and Performance in American Industry,' in Dosi G., D.J. Teece. and J. Chytry (eds), Technology, Organization and Competitiveness: Perspectives on Industrial and Corporate Change. Oxford University Press: Oxford.

Lazonick W. (1999), 'The Japanese Economy and Corporate Reform: What Path to Sustainable Prosperity?,' Industrial and Corporate Change, 8, 607-633.

Lewis M., Fitzgerald R. and C. Harvey (1996), The Growth of Nations: Culture, Competitiveness and the Problem of Globalization. Bristol Academic Press: Bristol.

Maddison A. (1995), Explaining the Economic Performance of Nations. Edward Elgar: Cheltenham.

Maddison A. (1996), 'Macroeconomic accounts for European countries,' in Van Ark B. and N. Crafts (eds), Quantitative Aspects of Post-war European Economic Growth. Cambridge University Press: Cambridge.

McMillan C.J. (1985), The Japanese Industrial System. De Gruyter: Berlin.

McMillan C.J. (1995), 'The State as Economic Engine: Lessons from the Japanese Experience,' Asia Pacific Business Review, 1, 1-16.

Morikawa H. (1995), 'The Role of Managerial Enterprise in Post-War Japan's Economic Growth: Focus on the 1950s,' Business History, 37, 32-45.

Morikawa H. (1997), 'Japan: Increasing Organizational Capabilities of Large Industrial Enterprises, 1880s-1980s,' in Chandler A.D., F. Amatori and T. Hikino, Big Business and the Wealth of Nations. Cambridge University Press: Cambridge.

Morishima M. (1982), Why has Japan 'Succeeded?' Cambridge University Press: Cambridge.

Mueller D.M. (1997), 'First-Mover Advantages and Path Dependence,' International Journal of Industrial Organization, 15, 827-50.

Nakamura T. (1995), The Postwar Japanese Economy: Its Development and Structure. University of Tokyo Press: Tokyo.

Nakayama S. (1991), Science, Technology and Society in Postwar Japan. Kegan Paul: London.

Nester, W.R. (1991), Japanese Industrial Targeting: The Neomercantilist Path to Economic Superpower. Macmillan: Basingstoke.

Nonaka I. and H. Takeuchi (1995), The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press: Oxford.

Odagiri H. (1992), Growth through Competition, Competition through Growth: Strategic Management and the Economy in Japan. Oxford University Press: Oxford.

Odagiri H. and A. Goto (1996), Technology and Industrial Policy in Japan: Building Capabilities by Learning, Innovation and Public Policy. Clarendon Press: Oxford.

Odagiri, H. and H. Yasuda (1997), 'Overseas R&D Activities of Japanese Firms,'in Goto, A. and Odagiri, H. (eds), Innovation in Japan. Clarendon Press: Oxford.

Okada Y. and S. Asaba (1997), 'The Patent System and R&D in Japan,' in Goto A. and H. Odagiri (eds), Innovation in Japan. Clarendon Press: Oxford.

Okazaki T. (1994), 'The Japanese Firm under the Wartime Planned Economy,' in Aoki M. and R. Dore (eds), The Japanese Firm: Sources of Competitive Strength. Oxford University Press: Oxford.

Okimoto D.I. and Y. Nishi (1994), 'R&D Organisation in Japanese and American Semiconductor Firms,' in M. Aoki and R. Dore (eds), The Japanese Firm: Sources of Competitive Strength. Oxford University Press: Oxford.

Ordover J.A. (1991), 'A Patent System for Both Diffusion and Exclusion,' Journal of Economic Perspectives, 5, 43-60.

Oshima K.(1987), 'The High Technology Gap: A View from Japan,' in Pierre A.J., A High Technology Gap: Europe, America and Japan. Council on Foreign Relations: New York.

Porter M.E. (1990), The Competitive Advantage of Nations. Macmillan: Basingstoke.

Price J. (1997), Japan Works: Power and Paradox in Postwar Industrial Relations. Cornell University Press: Ithaca.

Sato K. (1987), 'Saving and Investment,' in Yamamura K. and Y. Yasuba (eds), The Political Economy of Japan: Vol. 1 The Domestic Transformation. Stanford University Press: Stanford.

Scher M.J. (1997), Japanese Interfirm Networks and Their Main Banks. Macmillan: Basingstoke.

Schroeder D.M. and A.G. Robinson (1993), 'Training, Continuous Improvement and Human Relations: The US TWI Programs and the Japanese Management Style,' California Management Review, 35, 35-57.

Shin J-S. (1996), The Economics of the Latecomers: Catching-up, Technology Transfer and Institutions in Germany, Japan and South Korea. Routeledge: London.

Shinohara M. (1982), Industrial Growth, Trade and Dynamic Patterns in the Japanese Economy. University of Tokyo Press: Tokyo.

Sigurdson J. (1995: 3rd ed), Science and Technology in Japan. Catemill International: London.

Steven R. (1996), Japan and the New World Order: Global Investments, Trade and Finance. Macmillan: Basingstoke.

Sugayama S. (1995), 'Work Rules, Wages and Single Status: The Shaping of the Japanese Employment System,' Business History, 37, 120-40.

Suzuki Y. (1991), Japanese Management Structures 1920-1980. Macmillan: Basingstoke.

Tabb W.K. (1995), The Postwar Japanese System: Cultural Economy and Economic Transformation. Oxford University Press: Oxford.

Teece D.J., Pisano G., and A. Shuen (1997), 'Dynamic Capabilities and Strategic Management,' Strategic Management Journal, 18, 509-34.

Teramoto Y., F-J. Richter, N. Iwasaki, T. Takai and Y. Wakuta (1994), 'Global Strategy in the Japanese Semiconductor Industry: Knowledge Creation Through Strategic Alliances,' in Campbell N. and F. Burton (eds), Japanese Multinationals: Strategies and Management in the Global Kaisha. Routledge: London.

Tidd J., J. Bessant and K. Pavitt (1997), Managing Innovation: Integrating Technological, Market and Organisational Change.Wiley: Chichester.

Tiratsoo N. (2000), 'The United States Technical Assistance Programme in Japan, 1955-62,' forthcoming in Business History.

Turner L., D. Ray and T. Hayward (1997), The British Research of Japanese Companies. Insight Japan: London.

Vestal J. (1993), Industrial Policy and Japanese Industrial Development 1945-1990. Oxford University Press: Oxford.

Westney D.E. (1994), 'The Evolution of Japan's Industrial Research and Development,' in Aoki M. and R. Dore (eds), The Japanese Firm: Sources of Competitive Strength. Oxford University Press: Oxford.