INTO THE TWENTIETH CENTURY:

Patterns in the Relations between Science, Technology and the State during the Early Industrialisation Process

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Prologue

The dimensions of the "technology problem" in today's underdeveloped nations are very much shaped by complex social and economic factors which are external to the techniques themselves. Such factors embrace those operating within national economies (eg., factor price distortions within domestic markets) as well as those emanating from the international economy, (eg., terms of trade effects or the transfer pricing operations of transnational corporations). But it should also be emphasised that the nature of technology as a *physical entity* conditions many aspects of the process of underdevelopment. Thus the transfer of technology from one area of advanced technique to one of lesser development (eg., from Belgium to Russia in the later nineteenth century, from Japan to Malaysia today) involves for the 'receptor' nation not only prices and commercial judgements but also cognitive dissonance, public doubt, and the loss of trust in those things that were hitherto considered certain; as bicycles make way for cars, roadways are replaced by railways, stores by offices.

Discontinuous technological change means a shift in rules, regulations and the way things are done, change which must be accepted and conformed to (if not properly understood) by many individuals and groups whose daily lives and expectations lie beyond the pale of the education, certainties and powers of those elites who wield modernised technologies in the names of either "civilisation" or "competition" or both. For instance, following Japanese and North East Asia experiences, many S.E. Asian nations today have raised their technological horizons relatively rapidly under the dual compulsion of joining the "civilised" world and at the same time using its tools to beat it at its own games. *Our first analytical position might read as follows: Although the initial transfers of technologies in cases such as later nineteenth century Japan or Russia or several nations of Asia in the present century were made possible by transfer mechanisms operating within the international economy, the successful adoption, adaptation* *and diffusion of such transferred techniques within these economies depended upon both the "technological imperatives" inherent in the techniques and the nature of the socio-economic institutions which either existed or were devised in order to settle the new technologies within their novel cultural frameworks* (1).

Technological imperatives are those characteristics of a particular technique, set of techniques or projects which together dictate the size of the technological lag between transmitter and receiver, and which set the skills, the scale, the factor bias, the environmental limits, the scientific content and the absorption capacity of the technology (2). Thus, technological change in British manufacturing and services prior to the 1840s was, on the whole, in advance of most other nations. That is, industrialisation in Britain did not involve a process of catching-up. In the main, manufacturing represented small-scale, fairly labour- and skill-intensive production which at times drew upon either discrete packages of scientific information, notably in the chemical industries, or upon the general principles of machinofacture (ie. machining processes), basic mathematics and mechanics, together with the frequent application of given artisan skills. In Britain, technological change was drawn-out, indigenous and therefore appropriate to the nation's own resources base, and was in its origins geographically and socially widespread (3). Until at least the 1840s there was little need for governments to spend scarce resources on the formalisation of industrial or technical training or upon industrial research. There is, indeed, no evidence yet assembled which shows that a reallocation of resources towards technical training or research in industry and services would have resulted in a higher rate of economic growth than in fact occurred prior to 1851 or even 1900. The indigenous origins and natural imperatives of the major techniques ensured that British industrialisation impinged insignificantly upon the services or graduates supplied by universities, colleges or formal institutions of higher learning, many of which remained at least moribund or at most healthy offshoots of a predominantly non-industrial and continuously powerful sub-culture (4). Steam intellect, the technological culture of the skilled and semi-skilled workers, was seemingly a sufficient vehicle for the retention of old skills or the inculcation of the new, for the harbouring of inventions and the encouragement of innovation (5).

In the case of later industrialisers, such as Germany, Russia and Japan, much of the modernised technique was transferred from abroad, and changed technological imperatives in such areas as steel production, shipbuilding, transport systems, heavy chemicals and the new machine industries dictated a vastly increased optimal scale of operation, more sophisticated scientific, control and skill inputs, and a movement towards more capital-intensive modes of production. Where the early period of industrialisation was associated with this type of transferred, discontinuous technological change the need for specific 'servicing' institutions was much greater than in the above-outlined, more evolutionary maturing of the British model.

In his *Imperial Germany*, Thorstein Veblen wrote of the advantages of industrial latecomers in being able to appropriate for themselves the latest technologies without being encumbered by vested interests in obsolete machinery and existing practices or rules-of-thumb. Believing ultimately in the liberating powers of both science and technology, he recognised and espoused the "penalty of being first" in industrial development (6). More than a decade later S.G. Strumilin likewise recognised that "the later a country starts along the road of capitalist development, the quicker the tempo of growth which it applies, catching up and overtaking its more mature competitors" (7).

Much more recently, Gerschenkron has argued that in later nineteenth century Europe, differences in the process of industrialisation between nations resulted from the variable characteristics of the "institutional instruments" or creative substitutions called up by the fact and recognition of relative backwardness. The resulting history of the "industrial spurts" in nations such as Germany, Italy, Austria, Hungary, Bulgaria and Russia is a rich matrix of institutional responses and innovations, ranging from financial organisation to technical services (8). Notions of challenge and response are uppermost. The greater the magnitude of the challenge, that is the degree of relative economic backwardness, then the greater is not only the magnitude of response but the degree of change in the quality of response. In this form of analysis social and economic processes are multiply interfaced. Not only may "obstacles" to economic development be essentially social and institutional in character, also "measurable aspects of economic change do appear in conjunction with aspects which in their very nature defy measurement" (9).

But such patterns and processes only occur when techniques actually *are* transferred, and this depends, as argued, on the nature of commanding technological imperatives, and on the responsiveness or appropriateness of receptor institutions, but also upon the character of *transfer mechanisms* and the modes whereby transferred techniques are "settled" into their new contexts.

Even in the nineteenth century, the transfer and control of complex technologies, from lighthouses and railways to textile factories and chemical installations, demanded the active presence of commercial clerks, artisans, foremen and a host of skilled lower managers and technicians. Such vehicles of transfer as patents, licences and trade marks had to be enforced and monitored, and this on a scale never before witnessed. The process of transferred industrial development had become highly institutionalised and was increasingly controlled by the State. The institutions of technology transfer, of technical and scientific diffusion and training, and the ancillary servicing of new technologies emerged as one complex within a highly complex new world.

Science, Technology and the State: A Theory of Sequencing

Until very recently, the theme of "science, technology and the State" faced a cool intellectual climate. The technical advances in "neoclassical" economics over the post-war years and the practice of political regimes on both sides of the Atlantic combined to convert a fairly academic perspective on the optimising effects of individual sovereign choices exerted in free markets into a political dogma: markets were *inherently* superior in producing economic growth and increased welfare under all circumstances. Contrawise, non-market institutions, particularly those associated with State interference, were inherently inefficient and welfare-reducing in the long run. Furthermore, a dogma which might have found some relevance when applied to mature capitalist economic systems was increasingly applied to economies of quite another type, to the poor nations of South America, Africa and Asia. In extreme forms this postulated that in the absence of political reforms associated with liberalised market forces, *sustained* economic growth was impossible (10).

More recent acknowledgment of the frequency and significance of "market failures", recognition of the spectacular success of Pacific industrialising nations whose growth appears to be an outcome of novel forms of government stimulation, and the rise of a new institutional economics has begun to redress the balance. Neoclassical approaches may well provide some technical and operational 'solutions' to problems of distribution and production within mature capitalist economies, ie. in those many cases where there exists a strong framework of the market mechanism and where already established property rights are in place. In all other cases, the institutionalists insist that the market is merely itself an institution, whose evolution is conditioned by the State and whose final functions emerge only through a period of competition with other, contending institutions (11).

The fundamental weakness of the conventional economistic approaches was that they failed to acknowledge the trajectories, sequences and disturbances which determined the respective roles and strengths of State and Market, thus conflating and confusing the imperatives of modern capitalism with those of developing systems. Starkly, the non-historian and non-Asianist, Milton Friedman was nevertheless firm in his judgement that, historically, "reliance on the market in Japan released hidden and unsuspected resources of energy and ingenuity", and, indeed, that during early industrialisation, the "Japanese adopted the policies of Adam Smith" (12). This sort of claim clearly ignores the salient features of government activity during Meiji industrialisation – massive redistributionist measures, deficit financing, high military expenditure, *deliberate fostering* of market mechanisms and so on (13). We conclude that any approach to the State and industrialisation, and thus to an understanding of the dynamic importance of science and technology, requires an uninhibited view of sequence, trajectory and conjuncture. *Our second major analytical position is thus: Appearances notwithstanding, approaches to the relationship between science, technology and the State which fail to distinguish between the past and the present, or between capitalist maturity and early industrialisation, are unlikely to possess any generic interpretive power.*

We may begin anew with a simple heuristic: State interventionism may be captured at three overlapping levels, those of 1) the political undergirding of market forces and ideologies; 2) direct agency and; 3) the formulation of specific economic policy, a function of *government* itself.

The first level accords with characteristics of State involvement identified by a range of writers, from Karl Polanyi to Douglass North (14). Thus, for Macpherson, the prime task of the Meiji State in early Japanese industrialisation was "to introduce a socio-economic and legal framework compatible with development" (15). We might highlight the importance of this to technical innovation with reference to risk. For the technical innovator, the perception of risk might be a central component of the decision to persevere. The constantly adjusted internal calculus of the innovator embraces that which is being risked, the degree of risk, the likely depth of the potential failure and the upward incline of the path back to personal financial and social recovery. Seemingly, all four of these components of risk calculation, but particularly the last three, may be at least partially affected by State activity eg. in the areas of property rights, information dispersal, market protection, penalties for debt and so on. The State may establish the nature of institutionalised systems which in turn help determine the bounded rationality of individuals and collectivities.

It may be just as strongly suggested that the State's principal role in stimulating technological change at "level 1" (above) is performed through the reduction of *resistance* to technological change. Often resitance is dealt with by analysts as nihilistic or "Luddist", as if it is solely the province of the unlettered outsiders or of interest groups directly affected by technological change. Chart 1 below complicates the picture somewhat.

Given that widespread technological resistance acts as a high *risk* factor for potential innovators (entrepreneurs and technicians) then it is at least possible to interpret a very wide range of State activity as belonging to level 1 "interventions" and as having relevance to the degree of technological change that is socially feasible. In those cases where technological resistance occurs within "culture" itself (3 in Chart 1) then it is reasonable to posit that the State's industrial programme is, in effect, illegitimate. On the other hand, resistance stemming from the "intellectuals" may be addressed through a policy of persuasion or through promotion of individuals into new educational and bureaucratic hierarchies. During periods of early industrialisation, resistance may well take the form of revolutionary ideologies which deny the legitimacy of the State's programme, but such ideology must itself seek legitimacy through the conversion of vested interests (1 in Chart 1) or of key figures representing the two great classes of industrial modernisation, managers and workers.

The second level of State intervention is that of *direct agency*. Here the historian of science and technology is on more familiar ground. The nineteenth and twentieth century developmental states (from Russia and Japan through to the present newly industrialising

Chart 1. Technological Change: Types and Resources of Resistance

Level	Type of Resistance*	Sources of Resistance	
1.	VESTED INTERESTS; (a) Capital (b) Labour	Assets (physical) Organisations Incomes	
2.	INTELLECTUALS**	Principles Organisations	Interests Careers
3.	CULTURAL	Institutions Bureaucracies	Ideologies Norms

(*) Primarily in this analysis referring to 'adoption-diffusion' processes, but might extend to conditions and character of original innovative processes.

(**) Here we are thinking of intellectual resistance to significant technological discontinuities (eg. during technology transfer in 1880-1890s Russia, or in India during the 1950s) but the notion might be extended to "science" once it is acknowledged that conventional training, induction and recognition promote *necessary* resistance in complex scientific systems just as they also generate regular puzzle-solving. In this view some degree of resistance to change is essential to the continuation of any complex system.

countries) have directly bolstered national scientific and technical capabilities by R+D investments, officially induced transfers of technique, educational reforms, experimental stations, model factories, infrastructure building, government laboratories and testing installations, including measures for standardisation, and, of even greater impact, direct investment in innovative industries and direct orders of sophisticated equipment from the private enterprise sector.

The third level of intervention relates to the formulation by individual *governments* of specific economic policies which more or less *indirectly* govern the trajectory of public science and the patterns of technological innovation and transfer. Thus tariffs, quotas and exchange controls may determine raw material availability and the range of process technologies imported; interest rates and investment policies may be a major consideration for private enterprises when calculating the optimal investment in R+D activities within individual sectors or regions.

Historians of technology have, generally, but not invariably, treated levels 1 and 3 as beyond the scope of their enquires. Only the tools and levels of direct agency are of relevance. Within this perspective, the German state of the later nineteenth century "supported science" *more* and *better* than did the British state of the same period, because it invested in new universities and polytechnics and encouraged the movement towards public science and enterprise research. Such partiality or narrowness of focus is unlikely to yield good history – or, indeed, good policy. *A third analytical position emerges: Judgements about the role or effectiveness of the State in the advancement of science and technology in one nation in one period must recognise the indirect impacts (positive and negative) of its more general socio-economic policies.*

It would be tempting to visualise levels 1 to 3 as approximately chronological; that government intervention in any nation evolved from an increasingly generalised political undergirding of market forces, through direct agency, towards the formulation of sophisticated policies of economic management and fine tuning. But even in the British case, commonly visualised as nearest to an idealised "Western" model, government interaction took place or matured through a series of overlapping sequences. The eighteenth century was a period in which mercantilism only slowly and unsurely gave way to a more liberalised market regime, and this process was one at least partly engineered by the State itself. A general process of economic growth and market development *preceded* both industrial revolution and wholesale political change towards democractic institutions. As late as the year of the great exhibition of British technological superiority (1851), Britain was not nearly a democracy. From Adam Smith to John Stuart Mill, the period of the later eighteenth century and early nineteenth century witnessed the Statist underpinning of market forces and liberal ideologies. But both prior to and during this process the State intervened in the economy at both levels 1 and 2 through its implementation of policies concerning property and intellectual rights (eg. patents), taxation, shipping, product and export premiums and rewards, poor relief and policing, emigration of workmen and engineers and, of course, tariff and other trade protection (16). In the eighteenth century debate over tariffs there was encapsulated major perspectives on the State's task in generating national scientific and technical capacity. The great David Hume advocated free trade policy not primarily on the conventional grounds of the gains from specialisation but because trade was the *principal* means of increasing and monitoring technological supremacy. Whatever the balance of trade, international exchanges allowed Britain to "adopt, in every art, the inventions and improvements of our neighbours". To Hume, imports should not be viewed with dismay, for thereby "the art itself is gradually imported, to our visible advantage". Without this constant stimulation the mechanical arts "must fall into a State of languor and lose that emulation and novelty which contribute so much to their advancement" (17). In opposition, a mercantilist defence of tariffs was made by Richard Watson, sometime Professor of Chemistry at the University of Cambridge. Watson deplored the threatened reduction of the Anglo-French tariff in the 1780s on the grounds that this would make available to France the "mechanism, presses, dies and tools" upon which British supremacy depended (18). Seemingly, then, contemporaries were not unduly troubled in viewing trade policy as "Science and technology policy" in another guise. In particular, for David Hume and his followers, it was the State which would lead the open economy into the final victory over diminishing returns.

A major purpose of the present paper is to develop the following (fourth) analytical position: Within any nation, the ad hoc evolution of State policy towards industry is periodically punctuated by exogenous factors, and a major example of this is to be found in the phase of "late development" which occurred in Europe and in Japan in the years approximately 1870-1914 (see prologue). In this first climacteric, the major vehicle of transferred development, technology transfer, exerted enormous pressure on "receiver" nations who were situated beyond the metropolis, very few of which were able to capture and absorb its production potentials. Those nations that did transfer advanced technique successfully became the winners of the twentieth century, and included Germany, Italy, Russia and Japan amongst several others. Furthermore, Section IV of this paper argues that the years since approximately 1971-73 represent a second climacteric in which a group of nations beyond the metropolis and predominantly situated in East Asia, have utilised a variety of transfer mechanisms to dramatically shift into industrial modernisation. In both climacterics, whose starting points are one hundred years apart, the process of technology transfer effected a massive disturbance in the evolution of State economic policies and a significant alteration in the relationships between national science, technology and economic development.

Science, Technology and the State in the First Climacteric

The first climacteric was dominated by the simple fact that "catching-up" with the core leaders (especially with the USA and Britain) involved drawing upon institutional and informational resources from *both* "market" *and* "state" which were not available in relatively backward economies. Indeed, it was the relative absence of such institutional or administrative features in nations like Austria or Germany or Japan which dictated the central presence of the State and its efforts in the mobilisation of science and technology. The more relatively backward the economy and the more significant its industrial drive, the more science and technology were institutionalised and appropriated by the bureaucratic State. In essence, in the absence of a prior history of legitimate Statist involvement at level I (Section 1 above) speedy industrialisation *neces-*

sitated a rapid development of State activity at level 2, that of more or less direct agency. Whilst great liberal scientist-bureaucrats in Britain, such as Lyon Playfair, may have sincerely believed that the "cultivators of abstract science are the horses of the chariot of industry", the deliberate harnessing of the two was left to the bureaucrats of industrialising but relatively backward nations, and was only most tardily instituted in the greatest capitalist economy of all. A central feature of the late nineteenth century climacteric was the continued emphasis of the British State on the undergirding of market forces and a further ripening of democratic institutions, just as late developers shifted increasingly to direct action. The institutionalisation of science and technology has often been told as a slightly occidental and whiggish story of expertise, professionalisation and specialisation, but the emergence of such features of Western technocratic culture were surely hastened and given direction through more underlying politico-economic forces of the climacteric.

An illustration of such points is provided in the much noted contrast between the British and German systems for science and technology. Where the British State continued its established *ad hocism*, the Germans intervened in the higher scientific and technical learning on a relatively lavish level (18). Superior provisions meant that the Prussian university itself became a model: by the 1890s some 10 % of all Prussian University students and 13 % of polytechnic students were from other nations (20). More strategic State research was undertaken on behalf of government ministries in institutions specifically created for that purpose, especially in the fields of defence, health, veterinary science, crop protection, transport and communications, and the establishment of technical standards and controls. Unification brought with it an *increased* focus on imperial goals – resource-exploitation, testing, standardisation, and the development of colonial applied science, particularly in Africa. The combination of strong private interests and State support associated with the first national research institute, the Physikalich Technische Reichenstalt of 1887, was symptomatic of the late development model (21). The year of the Kaiser Wilhelm Gesellschaft (1911) was also the year of the Imperial Textile Bureau and the Imperial Chemical Institute (22). Speed, scale and government involvement combined to provide a rich medium for the followership of the private sector, which also operated in partnership with the State (23). By 1900 the German dyestuffs industry represented 90 % of the world's total output and was very heavily engaged in the provision of scientific facilities and personnel, not only their employment (24). Well over 1000 chemists were employed in dyestuffs alone : Hochst (Meister, Lucius and Bruning) were employing 307 chemists and 74 engineers by 1912 (25).

Keeping the national scientific and technical system "open" in the manner advocated by David Hume (Section 1 above) and required for large programmes of technology transfer, also meant the introduction of virile foreign ideologies (socialist, nationalist and liberal), foreign business and other practices, and threats to entrenched elites (see Table 1 above). That is, late development required an openness to technological influences which at once threatened underlying stabilities or continuities. Here the policy and the bureaucracy of the State were essential, and the history of statist undergirding of fast industrial change in nations such as Germany and Russia is well-enough established.

At first glance, Japan appears to be an exception. The first Asian industrialisation is often interpreted as all but symbiotic with Western technique, ie. enjoying a relationship with the West that was at once benign and to the unchallenged advantage of the Japanese body politic. This bland position is inaccurate. Technology transfer and the industrial and institutional changes associated with it did not go unchallenged and positive resistance to new techniques and associated new institutions appeared at all levels (26). This was especially so in the crucial years from 1874 to 1881 when a vast number of technological and institutional innovations were introduced. In the vanguard of change was the army itself, and even the military elite were by no means immune to physical resistance. In January of 1879 there occurred serious riots of the Imperial Guard at Takebashi Imperial Barracks in Tokyo, including a direct armed attack on leading government figures (27). During the period when the *mechanisms* of transfer dominated the national scientific and technical effort and were at their most open, vulnerable and public (eg. internal machinery competitions, external exhibitions, model factories and arsenals and so on), resistance and riots were endemic. An excellent example of this was the resistance to the modernised medical techniques which were introduced during the cholera epidemic of 1879 (28). Resistance to the new hospitals and to sanitary legislation required a massive police and military presence. A political element was present – *shizoku* (or ex-*samurai*), many of whom resented the social displacements inherent in urbanised industrialism, led rioters in attacks on police stations, on hospitals and on the foreign community, seen as arch-representatives of Westernism (29).

At a generalising level, a fifth position emerges; *The evidence of the late nineteenth century suggests that industrialisation of the nations beyond the metropolis involved Statist penetration of the industrialisation process, from direct technology transfers to measures of overt social controls, and that within this complexity the institutions of science became more formalised and increasingly harnessed to industrial requirements, particularly through the application of advanced knowledge and technique to the building of new public infrastructure and strategic industries.* For instance, the contrasts between Britain and Germany in the characters of their scientific and technical "cultures" were not fundamentally formed of contrasting cognitions following from differing "national cultures" but were outcomes of contrasting politico-economic contexts.

Beyond the Metropolis: Case Studies of Japan and Russia

In the course of his sweeping and highly informed history of Japan, Edwin O. Reischauer offers a fairly standard, generally accepted account of the industrial transformation of nineteenth century Japan:

> *The forty-five years of the Meiji period was essentially a time when the Japanese studied, borrowed and gradually assimilated those elements of Western civilisation which they chose to adopt... The Japanese determined to learn from each Western country that in which it particularly excelled... They saw at once that a technically competent populace was a prerequisite for a modern power... Western science and cheap oriental labour made an excellent combination for low-priced production* (30).

Note the vital elements : *cognition, intent, action, resources, success.* Who precisely *were* "they", what precisely *was* "Western science" ? Who did the "choosing" and how did they force compliance upon others, be they labourers, potential entrepreneurs or provincial bureaucrats ? Upon any reflection, Reischauer's statement is problematic. If cognition and intent were ever the keys to development in the climacteric then the whole world would now be rich and (presumably) happy. If endowments were crucial then the present pattern of world income distribution would be quite other than it is, with Indonesia more highly ranked than Japan. Development beyond the metropolis during the first climacteric poses real questions of action, agency and social control and requires that we reconsider the roles of such elements as scientific change, technological progress and institutional innovation, move such elements towards the sort of central position in analysis which has hitherto been occupied by the more conventional factors of capital, labour and entrepreneurial endeavour.

Contemporary Western residents in Japan were quite firm in identifying the government as the only agency of change :

> *The country is burning with eagerness to acquire the knowledge of the West, it behoves the government to supply this knowledge through pure channels and to superintend its absorption into the body Politic in the manner best suited to be a valuable reproducing agent.* (31)

Many of the Japanese themselves were more cautious. Government might establish and monitor the Western influence, institutionalise science and technology, but the forging of a precise, open relationship with Western agencies was necessary in order to ensure success in the longer term. Unrestrained foreign capital might destroy indigenous capacities, but on the other hand foreign enterprise was a requirement of the learning process. The debate on the role of foreign capital and its link with foreign knowledge and technique raged throughout the 1870s and 1880s. The *Chūgai Bukka Shimpō* developed a coherent view of the Japan-Western relationship. Joint enterprise should involve the foreigner as provider of equipment and know-how, but "*for all other* things, except this, the native material and labour may be employed". Foreigners would operate within Japan but at arms length :

> *the money expended therefore would all remain in Japan, and thus, what foreigners would actually gain would only be the net profit, after having deducted all [Japan based] expenses: ie. original value. [Where there was joint capitalisation] the net profit too would have to be divided according to the amount of the respective shares.* (32)

But only *government* could ensure a proper monitoring of the Japan-West interaction, and from an early stage the Japanese government rejected foreign capital as dangerous (33). The prohibition on foreign enterprise operations within Japan had a variety of consequences, the first of which was the continual need for government to keep the lines of communication open, the mechanisms of transfer varied and competitive and the ultimate users of foreign technology as well informed as feasible. In contrast, in Russia the haphazard entrance of foreign enterprise in the eighteenth and early nineteenth century meant that the concentrated industrial drive of the 1890s was from the beginning geared to foreign capital (34). As the chief instigator of the industrial drive, Finance Minister Count Sergei Yullevich Witte (1845-1915), put it in a private note to the Tsar in 1899:

The influx of foreign capital is, in the considered opinion of the Minister of Finance, the only way by which our industry will be able to supply our country quickly with abundant and cheap products. Each new wave of capital, rolling in from abroad, knocks down the excessively high level of profits to which our monopolistic businessman are accustomed and forces them to seek equal profits through technical improvements which lead to price reductions. (35)

Foreign enterprise meant a competitive flow of knowledge and machinery. The State would not directly invest in new industry and technique, rather it would dictate the character and direction of Russia's technological interactions with advanced industrial nations by investing in infrastructure and military sectors and by providing an environment of protection and bounty beyond the metropolis.

The first lesson from the experience of Japan and Russia is that early Statist decisions concerning the character (as against the *extent*) of interaction with more advanced systems impacts directly on the *subsequent* development of transfer mechanisms, modernist institutions and private sector participation. State decisions over foreign capital at least partially set the conditions within which policies relating to science and technology would emerge. In terms of our discussion in Section 1 above, government intervention at levels 1 and 3 determined the nature of its activities at level 2.

Of course, Russia shared more or less in the scientific and technological enterprises of Western Europe long before the concerted industrial drive of the 1890s. Statist interventions in scientific and technological enterprise dominated the early nineteenth century, including the contributions of the College of Mines which guided Charles Baird in his purchase of peasants for factory labour in his Westernised foundry and machine works, through State regulations which permitted foreign artisans and technicians to become registered and protected members of the guilds, through money and land grants to foreign enterprise for the erection of sericulture and silk weaving establishments under stipulations that Russian apprentices would be trained in the projects, to the encouragement of the partnership of John Hughes and A.N. Pol in the foundation of a modernised Ukrainian iron industry and the financing of Hughes' New Russia Company; by 1894 the latter enterprise employed 7500 men and centred on a core of British machinery and skilled workers (36). The Russian State maintained the "communities" of foreign artisans in metallurgy, coalmining, chemicals and electrical engineering.

An essentially *ad hoc* policy involved interventions at all levels 1-3 (Section 1 above) in the years *prior* to the initiation of the massive and dominant South Russia metallurgical project (circa 1887-1900). By that time Russia represented a significant if peripheral component of Europe's scientific and technical enterprise. Thus although Imperial Russia might send students to Western Europe for training in the pragmatics (law, commerce, machine technology), the nation's scientists were creating international-level breakthroughs in such areas as probability theory, crystallography, bacteriology, soil science, immunology, embryology and the new chemistry (37).

In contrast, Japanese industrialisation was contemporaneous with the selective transfer of Western science into an isolated and hitherto immiscible cultural and social setting. Until the industrial drive of 1868-1884 both Statist restrictions and neo-Confucian ideology had emphasised the values of personal loyalty and hierarchy. They thus, at least partially, led to a stultifying sectarianism in most areas of intellectual life. Status and caste differences meant that knowledge could spread effectively between locations within groups but not easily between groups, whilst hand-mind distinctions attached to class separated technique from knowledge and, as Bartholomew has convincingly argued prohibited any fruitful communication between natural science and mathematics (38). So, if anything, Statist intervention prior to 1868 confirmed the *status quo*, permitted a highly controlled and very limited communication with the West, and reduced 'science' to a technical instrumentalism which was not associated with industrialisation or social change. In turn, Japanese intellectuals spent a deal of effort in "translating" Western science and technological culture into basic Japanese cultural meanings (39).

The industrial drive involved a relatively speedy transformation of the nation's scientific community on the basis of a continued, controlled selective elitism: although *samurai* had represented perhaps 5 % of the total population, 53 % of "Westernised" scientists as defined prior to 1920 were *shizoku*, or of the ex-samurai stratum (40). State institutionalised intervention provided the *modus vivendi* of transformation ; 70% of "scientists" were trained at the first and principal state showcase, the Imperial University in Tokyo, a major centre for the employment of *Western* scientists (41). It was Japanese officialdom which determined that the influence of Britain would give way to that of Germany during the 1880s, and clearly this switch had an impact on the character of the subsequent Japanese scientific enterprise, including the theoretical physics of Ishihara Jun, the geophysics and magnetism of Tanakadate Aikitsu and the outstanding bacteriological research of Kitasato Shibasaburö. Bartholomew has argued recently that it was the guided German connection which influenced the Japanese research programme in terms of such features as completeness and thoroughness (42). A second lesson of the Japanese and Russian cases is that the exigencies of fast development during the climacteric demonstrate the large initial difference between those nations beyond the metropolis and the metropolis itself, but (as success accrues) *reduce* the initial differences *amongst* the newly industrialising nations during and after the phase of the industrial drive.

A third and perhaps more fascinating aspect of the two cases of Japan and Russia is that they appear to conflict with the general notion that successfully transferred development depends somewhat upon especially constructed, close relationships between the metropolitan leader and the potential winners lying beyond the metropolis. Clearly, during this first of the modern climacterics the British economy lay at the centre of a global economy which embraced all of the significant mechanisms of transfer – centres of learning, patent systems, skill migration, capital goods and so on. Yet Japan did not import British capital (see above), the Japanese government did not forge alliances with British producers or favour British suppliers of machinery. Russia financed its industrial modernisation from France and Belgium rather than from Britain, and with the exception of John Hughes (above) the great bulk of foreign capital and enterprise originated other than in Britain. In addition, in both Russia and Japan the machinery exports of Britain faced very stiff competition from those of other nations, especially Germany and the USA, the principal members of the commercial metropolis beyond its leadership. It is true that during the crisis of 1901 Witte attempted to forge a closer relationship with Britain, but this did not reflect the reality of the dynamical changes of the 1890s (43).

A fourth lesson of the first climacteric seems to be that a principal function of the State is *institutional.* The new institutions of science, especially the research university and government agencies (level 2 of intervention) were created by the State alongside institutes of social control, finance, education and training and indoctrination (levels 1 and 3 of intervention). This was recognised at the centre of the metropolis at the point when Japan defeated Russia in physical warfare (1905):

> *the lesson which our educationalists and statesmen have to learn from Japan is that the life of a modern nation requires to be organised on scientific lines in all its departments... it must be consciously used for the promotion of national welfare.* (44)

The Japanese scientific and technological enterprise was vastly stimulated by the employment opportunities speedily made available not merely in universities, colleges and ministries but in the institutions for the regulation of new strategic laws (e.g. the Promotion of Navigation and Shipbuilding Law, the Electrical Power Supply Enterprise Law), for intellectual property rights (e.g. the patent system), the vast expansion of low-level technical training and in the manning of Statist innovations in metrication, standardisation and specification eg. in government contracts for supply of raw materials (45).

A fifth general point of the case studies is that success was sustained through the emergence of military-industrial complexes which were at the hub of government strategies. Both Japan and Russia spent a disproportionately large amount on military enterprise (46). Whatever its short-term costs and imbalances, military demand mobilised resources and served as a principal means whereby existing techniques were challenged, revamped or replaced. Whilst demand for railways and telegraphs, keys to military preparedness, lay at the centre of the Russian metallurgical projects, in Japan modernisation of armaments included a greater specification of product qualities, more sophisticated transfers and a process of trickling-out of best technique from arsenals and dockyards towards private enterprise (47).

The notion of 'followership' leads to some consideration of a most vital aspect of the cases, the relations between public and private sectors, or State and market. A more widespread, less centralised scientific enterprise awaited two conditions: 1) the steady emergence of an industrial, commercial and professional middle class, especially an increasingly urban location of that class and, 2) the emergence of diffused demands for scientific and technical services amongst the growing indigenous private enterprises in the most modernised sectors of the economy. Generalising somewhat wildly we might hazard that the first of these two mechanisms was especially present in the modernisation of the American scientific and manufacturing enterprises, the second mechanism of especial importance in the modernisation of the German scientific enterprise (48). Beyond the metropolis, similar forces were at work, although the greater the extent of relative economic backwardness the less likely that force (1) above would precede force (2) above. In Japan, followership based on the prior provisions of government was hastened during 1881-84 by the deliberate policy of privatisation of public sector enterprises, the so-called "selling-up" process (49). This was tremendously influenced by government expenditure on social control and basic education which together far outweighed expenditure on industry, or on science and technology, directly (50). At the micro lead, many Japanese and foreign scientific and technical experts found employment in the various levels of the technical education system, which expanded at a tremendous pace (51). In the case of Russia, "followership" is very well-illustrated in the South Russian metallurgical project in two phases of 1887-94 and 1895-1901. The first phase was foreign-led, centred on turnkey projects, was very highly modernised and large scale and involved skills across a wide range of industrial pursuits. Here all enterprises depended on government encouragement, guarantees and contracts (52). But the second phase of company expansion was less dependent on the Russian government and generated a far greater range of production, increasingly away from the railways towards shipbuilding and general engineering. This second phase represented the establishment of a modernised capital goods industry both creating and drawing in talents and skills from elsewhere in Russia. Competition between enterprises promoted speedy transfers and their diffusion to new enterprises and locations both within South Russia and beyond it in such diverse locations as Riga or the Southern Urals (53).

Finally, the case studies variously illustrate the multitude of Statist interventions within the transfer process itself, especially those concerning official promotion of transfer mechanisms. In both Russia and Japan, success during the industrial drives may have depended upon a period of *prior* government action in which new institutions and learning processes were generated. Even short-term "failure" may produce a result. For instance, in Russia during the 1870s large government investments had centred on modern technique in the Urals, Poland, Lugansk and Olonets. Although these were in the main unsuccessful, such interventions maintained the establishment of significant administrative and bureaucratic capacity prior to 1887, focused on an increasingly sophisticated Mining Department within the Ministry of Finance, a Corps of Mining Engineers and a government school of mines at St. Petersburg, all of which provided settings for accumulative foreign influence.[54] Secondly, the State was *the* vehicle which maintained an open door, particularly important in the far more isolated instance of Meiji Japan. No other major agency could have undertaken this role, which set the scene for competitive emulation in the private sector at a later stage (especially post-1890). At times of crisis or high risk eg. the late 1870s or early 1880s, government was the only agent capable of both quickly absorbing foreign expertise and then dispersing it to a large number of users in the form of new procedures or new equipment. Again, the Japanese prohibition on foreign capital necessitated a focal position for the State in maintaining the open door, whilst the need for both efficiency and ideological control required that the Meiji state should stand at that door as the *major domo* of the house of intellect and technique. The State was also important in promoting competition amongst the *foreign* suppliers of advanced technology, and thereby increased the *quality* of the flow of information and technology and thus the usefulness of the outside world as a resource with which to construct a national capacity for scientific and technological enterprise.

It seems that industrial development of nations beyond the metropolis during the first climacteric involved a fairly radical disturbance in the relations between science, technology and the State, sufficient to ensure a very varied inheritance of institutionalised forms in the twentieth century. We have suggested that variations in the way in which scientific enterprise is harnessed to technology, or in the manner of national support for both science and technology, may result primarily from the *initial* relative position from which nations pursued an industrial drive, rather than from inherent cultural or social distinctions between such nations. We have also suggested that successful industrialisation may depend on relatively rapid exploitation of fairly short-term opportunities offered by changes in the dynamics of the global industrial system, and that such opportunities occur mostly during periods of climacteric, during which there is a conjuncture of technological and institutional innovations beyond the metropolis led by non-democratic (not, by any means, identical to anti-democratic) governments pursuing "national" interests without recourse to the ballot box. *Success*, however, awaits the point when expensive government leadership is followed (not entirely *replaced*) by private sector interventions across a range of industries and institutions. In such cases, industrialisation *and* a movement towards market forces precede the fuller development of 'democratic' political institutions or liberalised ideologies. Liberal economics may even be pursued in the name of culturalism and nationalism. Democratic political institutions may only follow from strong movements for cultural and political change amongst new middle class interest groups, yet scientific and technological enterprise may have been mobilised to a significant degree by the demands of new industrial enterprises for new personel, technique and information, demands no longer satisfied by further transfers. It may, furthermore, only be through the survival over this crucial, relatively short period of industrial drive that national systems may then emerge which are more 'democratic' in conventional terms and in which ;'science' is seen as integral to the well-being of the body politic, not merely either instrument or a symbol of the 'advanced civilisation' lying within the metropolis. At this point the metropolis has been effectively redesigned.

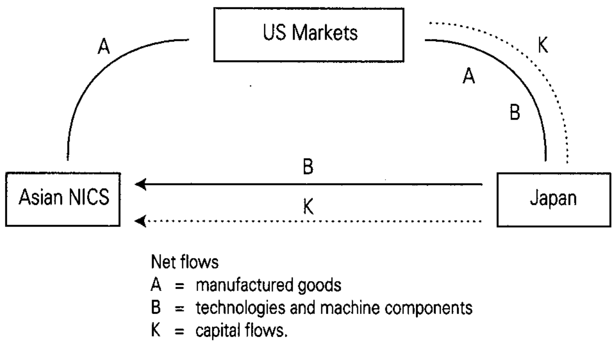
Beyond the Metropolis: A Second Climacteric

The most recent historical period, following the "golden age" of rapid economic growth in the years approximately 1950 to 1973 (55) has often been summarised as one of stagflation or global downturn and compared with the severe international depression of the years following the financial crises of 1926-29. We would argue that such a view is very misleading. The years since 1973 have been associated with a slowdown in growth of the older metropolitan nations, especially the USA, and the emergence to new leadership within the metropolis of Japan. Similarly, the years from 1870 to 1914 were dominated by the *relative* decline of the British economy and the rise of the USA and of Germany to leadership of the metropolis. But just as in the first climacteric, where the faltering of the leadership was associated with *both* a change in leadership *and* the relatively speedy industrial development of an entirely new group of nations, including both Japan and Russia, so the relative decline of the USA and Europe in the world system since 1973 has been contemporaneous with the dramatic rise of the newly industrialising countries (NICs) of East Asia and elsewhere (56). We may quite reasonably nominate the years since 1973 as representing the genesis and maturing of a second great climacteric, in which a new array of winners and losers has appeared. Furthermore, the industrial and institutional developments beyond the metropolis may be as clearly linked to the metropolis itself as was the case of the first climacteric. Once more technology transfer, institutional innovations, foreign trade and capital movements become of great significance, and once more the role of the State and the character of its relations with the private sector are seen as of extreme importance in explaining the sequence of events and the extent of success. Finally, as in the first climacteric, so too in recent years the technology transfer and institutional adjustments associated with climacteric processes have had significant consequences in the realm of scientific and technology enterprise, the contributions of governments to science and technology, and the way in which research and training are harnessed to the process of industrialisation (57).

Any satisfying elaboration of the dynamical features of the second climacteric clearly lies beyond the scope of the present essay, but Chart 2 begins to unravel some basic relationships and centres on the metropolis and industrialisation in East Asia (58).

The basic climacteric features of the simple model are as follows. The leadership and the size of the US economy permits a fairly lengthy process in which both the leadership is challenged and the leading nation is in receipt of net flows of manufactured goods, new product technologies and large amounts of Japanese capital in various forms. By this feature alone, the model is transitional. A great range of arguments have been offered in order to explain the position of the USA, but it is becoming clear than an interpretation of the relative decline of the US economy since the early 1970s must incorporate the degrees of success in which "follower" nations (such as Japan and Germany) shrank the technological gaps between their own systems and that of the USA, the failure of the 'mature' US institutional system, especially in those areas concerned with education, training and social consensus, and the strains imposed on the US by leadership itself, particularly in terms of the valuation of the US dollar prior to 1985, defence commitments and the complexity of policy issues – the latter has been decidedly

Chart 2. The Maturing Climacteric: The USA, Japan and the Asian NICs in the 1980s



increased through continued global responsibilities, perhaps to such an extent that *no* new US political regime may escape the dominant pressure of existing military, bureaucratic and diplomatic structures (59). This compound of forces allows for great ironies and the coexistence of the seemingly irreconcilable: the invention of transistors, semiconductors and computers and the fall in the US share of the world market in microelectronics, including the special markets for the highest-tech products within that industry (60). Furthermore, in this sort of argument the "underlying" failure of the US economy lies in a failure of enterprise investment and technological innovation, but also allows that such failures are themselves the essential *modus vivendi* of yet deeper fractures of leadership: the inability of the institutional structure to induce innovative investment and technological behaviour (61). The so-called "culture" of US private enterprise forbids long-term technological change and itself results from deeper features associated with the very fact of leadership (62). Thus the US economy spawns larger and larger trade and budget deficits on which, as can be seen in Chart 2, a portion of the dynamics of climacteric depends.

The position of Japan in Chart 2 derives from its earlier ability to transfer technology out of the metropolis and to join the metropolis during its two principal phases of "catch-up", the years of the first climacteric in which the nation joined the lowest ranks of the core set of industrialisers, and the "golden age" of growth around 1950-1973 during which Japan maintained an accelerating growth rate based on high rates of savings and investment, surplus labour supplies and technology transfer-in from the USA and Europe (63). By the 1980s the Japanese economy severely challenged that of the USA for industrial (if not growth overall) leadership, and the surplus savings of the Japanese economy were increasingly associated with America's dual deficits, with the Japanese ownership of US enterprises which had hitherto been considered as at the very heart of American culture and institutional life (64), and with the inability of the US to compete in key markets at a global level as it faced Japanese manufacturers whose production profiles included new manufacturing establishments operating outside of Japan itself, especially in East Asia. The process was hastened from around 1985 with the increased upward revaluation of the yen which had the principal effect not of halting Japanese exports to the USA, but of increasing the export of Japanese investment funds and techniques (to Japanese, foreign assets were now cheaper in yen terms) and of increasing the competitive advantage of some Asian NIC's exports at the expense of the more labour and energy using products of Japan.

Although the early position of the NICs was to a great extent a result of pull effects stemming from the USA from the early 1950s (65), the NIC growth of the 1980s was increasingly a result of changes in the Japanese economy; the increase in the price of labour, worsened pollution and overcrowding, movements away from oil-using industries, the continued high rate of savings and the need to replace foreign trade – increasingly under US pressure – with overseas production through the export of capital and the transfer of technique (66). The revaluation of the yen in the mid-1980s tightened the dynamic aspects of the model: Japanese capital and enterprise surged into the earlier NICs during the mid and late 1980s and then into the industrialising nations of South East Asia (e.g. Thailand and Indonesia) during 1988 and 1989 (67).

State industrial policies and policies towards science and technology in Japan and the NICs are demonstratively other than those of the older leaders of the metropolis. In the latter the relative failure of many sectors of private enterprise has been associated with a low commitment to science and technology and a growing dependence on public education and the R+D provisions of the State. Systems which thrived during the first climacteric on the basis of aggressive entrepreneurship and its sponsorship (if not organisation) of new forms of research institute and activity have become State-dependent. In contrast, the new winners of the second climacteric, Japan within the metropolis and the Asian-NICs as the first tier of winners (roughly comparable with the US and Germany on one hand and Japan and Russia on the other during the first climacteric) have combined early State tuition, financing and incentives with the R+D investment and demands of fast-growing private sectors. Derived from the reworking of data in the UNESCO *Statistical Yearbook* of 1986, Chart 3 illustrates the burdens of leadership and the felicities of followership in the area of expenditure on R+D (68).

Chart 3. Expenditure of Public Funds on National R+D by Selected Socio-Economic Aims (5 of 13 categories) % Fig.

		Space	Defence	Industrial Develop-ment	Energy	Advance of Knowledge
Japan	1983	9.2	5.8	12.6	29.1	3.6
USA	1982	5.5	64.3	0.4	6.7	3.9
UK	1981	1.9	48.8	6.3	6.4	15.2
Germany (Fed. Rep.)	1981	3.9	8.5	10.2	14.9	44.5

Defence R+D, which no longer may boast the much-vaunted potential spin-offs at low cost into the private sector, crushes the State-led R+D efforts of the older leadership of the USA and the UK. More so than Germany, Japan illustrates the liberations of followership through its higher expenditure on industrial development and closely associated energy development, and its much lower investment in the advance of knowledge. But Chart 4 illustrates something more.

Chart 4. Expenditure on R+D, Japan and USA (1983-1984)

		USA	Japan
1	All R+D as % of GNP	2.7	2.6
2	% of total expenditure R+D which is from productive enterprise	49.6	75.9
3	Current expenditure by productive enterprise as a percentage of all expenditure	73.0	64.8
4	Manufacturing R+D expenditure as a percentage of all productive sector expenditure	–	93.4
5	R+D as percentage of GNP deflated for expenditure on Space and Defence	0.82	2.21

Embracing *both* public and private contributions to national R+D, Chart 4 shows how Japan has caught up with the USA in terms of total R+D commitments, easily overtaken the USA in terms of R+D net of defence (row 5), and reversed the long-term historical trends in sectoral contribution : in Japan the private sector contribution to total R+D is of far greater relative importance than in the case of the USA.

By the end of the 1980s it was becoming clear that the scientific and technological enterprise of the NICs (eg. the Republic of Korea) was approximating that of Japan in a similar manner to the efforts of the late developers of the first climacteric in reproducing the essential institutional features of the metropolis of the first climacteric. Just as then, recent later industrialisation has been associated with the penetration of the economy by the State at all levels 1-3 as outlined in Section 1 above of this essay. Again, as in earlier years, the first focus was on the process of technology transfer itself, the need to encourage foreign information, technique and skills through the creation of an environment which both stimulated transfer and permitted emulation. However inefficiently and autocratically, the bureaucrats of the Asia NICs took on a prime task of searching and sifting of global technique, with the major partnership shifting most recently towards Japan and away from Europe and the USA. R+D enterprise (intervention level 2) was clearly influenced first by import substitution and then export promotion policies (intervention levels 1 and 3), but also by innovative institutional responses which approximate those of the most recent metropolitan leadership (ie. Japan) rather than those of the older leaders such as Europe and the USA.

As royalties mounted, as some strategic gaps were closed and as the professional middle classes within NIC economies began to exert voice rather than a continual quietest loyalty, so too the State-led mechanisms of technology transfer and uplift became somewhat more open and more directed towards indigenous users and national training programmes. After early experiments with metropolitan-style liberal arts education, most East Asian industrialisers moved fairly firmly towards appropriate vocational and technical training, polytechnics and applied groupings in universities (69). Of greater significance, the NICs began to selectively emphasise the role of enterprise sector training processes, so famous as a major characteristic of the Japanese system (70). Where the fractures of metropolitan leadership led to an outcry for a reformed system of public education in the UK or the USA, in Asia the harnessing of knowledge and technique to industry was increasingly seen as a task of the private sector, however aided and abetted by government : international comparisons of very crude aggregates do bear out this picture. Increases in business expenditure on R+D as a percentage of GDP between 1981 and 1991 averaged per annum 9 % for Japan and 4 % for the USA, but 32 % for S. Korea, 24 % for Singapore and 16 % for Taiwan (71). As shown in Chart 4, the trend is clearly as established earlier by Japan.

Thus the NIC States have emphasised the establishment of new institutional arrangements to address an increasing range of new disciplines. The Korean Advanced Institute of Science and Technology and the Industrial Technology Research Institute in Taiwan are good recent examples, representing new modes of R+D encouragement directly linked to both global technique and local industrial needs. By the later 1980s Korea and Taiwan were beginning to reach metropolitan levels in terms of expenditure on R+D as a proportion of national income, ie. around the 2 % figure. Again, efforts like that of Daeduk Science Town in Korea and the Hsiuchu industrial zone in Taiwan are clearly reflections of the Japanese emphasis on technology cities as illustrated at Tsukuba and in plans for multifunctional cities overseas (72). In contrast to the older metropolitan leadership, universities are not necessarily seen as the prime sites of higher level R+D or for the application of such to new industrial processes. Again, despite key differences in the underlying cultural assumptions of such institutional features, at the level closest to production itself, the East Asia NICs have also experimented with such innovations as the Japanese-style Quality Control Circle (73). Finally, the recent transformations of the R+D and technological profiles of Japan's small and medium scale companies, often neglected in models of Japanese development or the East Asia system, provides a potentially powerful exemplar for further institutional change in the NICs, dominated as they are by a high percentage of small and self-employed businesses: CAD/CAM systems need not await the increased size of enterprises operating in settings of increased industry output (74).

Although several commentators have stressed the inadequacies of East Asia R+D facilities, lack of creativity and quality controls, and a measurable absence of technological autonomy, such emphases omit the dynamics of climacteric transition (75). *No end points have yet been reached*, and to cut into historical trends or transitions as if they are equilibria is to miss the analytical point. Clearly, the inherent instability of major ingredients of climacteric (as shown in Chart 2 above) include the catch-up process, (the narrowing of technological differentials between nations) and the *reaction of the metropolis* as policy makers there realise the possible value of technological closure, ie. leading to a debilitating weakening of the "B" arrow linking Japan and the Asian NICs in Chart 2 above, itself merely a culmination of *earlier* technology transfers from the USA to Japan. That is, Asian NICs are in a real sense now in receipt of techniques derived initially from the earlier leaders of the metropolis, but adapted and filtered through the institutional and commercial operations of the expanding Japanese economy. Such relationships are amongst the foremost dynamical transition features of the second climacteric.

There are several parallels between the two climacterics which together point towards a historical sequencing in the relationship between science, technology and the State during critical periods of change. Accelerated industrialisation of "outlying" economies may be more associated with the emerging new competitors within the metropolis than with its leadership, whose greatest influence is likely to lie in the period just prior to industrial drive. Just as technology transfer into Japan and Russia prior to 1914 owed more to Germany, the USA and France than to Britain, so too much of the dynamics of the Pacific during the 1970s and 1980s may be best interpreted through key changes within the Japanese economy and in the relations between Japan and the USA. This may be related to the transfer of institutional modes as well. Japan's interest in British educational, technical and legal institutions faded somewhat during the 1890s just as a closer borrowing relationship was forged with the industrial newcomer, Germany (76). Similarly, the earlier development of the Asian NICs was associated with a period of 'Americanisation' which has seemingly been succeeded by increased Japanese influence.

The movement of capital into late developers appears to be of importance, but not necessarily at the point of initiation of the industrial drive and not of decisive importance in the absence of prior technological trading and contemporaneous institutional innovations. Much of the latter were determined by State interventions, many of which influenced the direction of science and technology development but few of which were aimed directly at R+D or the national scientific enterprise. That is, industrial development during the climacteric involves a concerted State involvement at all of levels 1-3 of those outlined in Section 1 above. It is possible to visualise a sequence which satisfies many of the prominent phenomena occurring within both climacterics. Chart 5 below, which follows also from Chart 2 above, depicts the sequence of changes observable in early British industrialisation (eighteenth and nineteenth century), during the first climacteric (late 19th C.) and during the Second climacteric (later 20th C.).

In this simplified model it is not possible to incorporate the great variety of non-metropolitan conditions or levels existing in nations prior to the industrial drive of block X. In this model, liberal political regimes or institutions do not 'cause' nations to jump the transformation gap from underdevelopment to industrial drive to industrial revolution. Indeed, the institutions of the market are created institutions and develop subsequently to industrialisation in all cases but that of the very earliest developers, particularly Britain. In the case of Britain, a unique and irreproducible case of industrialisation, early industrialisation occurred from a position of economic and commercial supremacy, under increasing Statist interventions during the 18th century, followed by

Chart 5. Paths and Punctuations: A Sequencing Approach to Industrialisation

Economic Status	Non-Metropolitan	Industrial Drive	Industrial Revolution	Metropolis
Economic Status →	State initiation X →		Guided Followership Y →	Democracy and Markets Z
Mechanisms	Technology Transfer Inst. Innovation Foreign Trade		R+D Inst. Innovation Foreign K Tech. Diffusion	R+D Inst. Innovation Tech. Diffusion
Caracter of State Interventions	2 + 1		1 + 2	3 + 1 + 2
Forces for S + T	A		A + B	B + C + A

Key: 2, 1, 3 = levels of State intervention as in Section I above, 1 = undergirding, 2 = direct S+T policy, 3 = specific econ. policy.
A = State provision of S+T resources and training for indigenous development.
B = Enterprise demand for indigenous S+T services and skills.
C = Rise of indigenous commercial and professional middle class.
K = Capital, R+D = research and development funding.
S+T = Science and Technology

some advancement towards a more democratic process during the industrial revolution itself. The British State undergirded the market and the market ideologies of liberalism and individualism and there was no pressure on the system or the sequence of events arising from wholesale transfers-in, of advanced technologies or institutions or disruptive "progressive" ideologies. The sequence of events in Britain was very long drawn out, from the Statist interventions and elementary science policies of the 18th century, through the guided followership of the early 19th century, associated with a rise of aggressive entrepreneurship and a host of new technologies, to the increased democracy of political institutions in the later 19th century (77).

During the period of climacteric, maintenance of social and political control is a prime concern of the State during the movement towards industrial drive and industrial revolution (blocks X and Y of Chart 5). Although, historically, non-metropolitan regimes are only rarely market democracies, during the early industrialisation of late developers the interventions of the State *increase* rather than decrease, a requirement of the essential, related processes of technology transfer and institutional innovation. Thus the historical sequence seems to involve a tightening of Statist controls *because* of institutional weakness, and a later emergence of "market forces" as private sector groups follow the technological and institutional leadership of the State. The important function of the private sector in block Y is twofold; to a) broaden the range of techniques and industries, moving modernising activity beyond the sites initially selected by the State, and b) increase the efficiency of modern sector activity, a process driven first by competitive emulation and then by the normal forces of the market (block Z).

The new industrialisers of the climacteric demonstrate phases of industrial drive wherein much of government activity is geared to technology transfer and to the strengthening of internal institutions of knowledge diffusion, education, training and technological demonstration. Within this process, organisations for science and technology are created which are quite unlikely to ape those of the erstwhile leadership of the metropolis. The political *and* the scientific and technical institutions of the winners in blocks X and Y are more *likely* to emulate those of the most vigorous elements of the metropolis e.g. in the 1890s Germany and the US became more appropriate models than the UK, in the 1990s Japan is a more apt model for East Asia than is the USA or Europe. Indeed, during the climacteric, new institutions for science and technology evolved in either or both of the metropolitan winners (e.g. Japan today) or the new industrialisers (e.g. Korea today) may pass towards the more established nations of the metropolis (e.g. Britain or America or Germany today) (78). The last row of Chart 5 suggests that in most cases science and technology will be *principally* supported by the State and then by the specific demands of the private sector (eg. later 19th century Germany or today's NICs) and at a later stage only benefit from a broader base of support arising from the growth of effective social power of new middle class groups. In this model the industrialisation of later 19th century Japan, for instance, *could not* have succeeded under a democratic regime. Similarly, in this model, calls for "democracy" and the swift removal or outright reform of absolutist or authoritarian regimes (whether socialist or nationalist) in late-developing nations may be contrary to the observable pattern of historical sequencing. This is *not* to say that human agency and novel institutions may not transcend discernible patterns, but merely that such patterns do seem to have recurred. Much radical and classical political economy at one time was devoted to the proposition that calls for democracy or democratic socialism are likely to fail in industrialising systems if new institutions are adopted prior to the attainment of industrial revolution, ie. block Y above (79). Furthermore, the example of the contemporary NICs and of China suggest that it is possible to initiate substantial reforms in market structures and in non-market institutions (which will accelerate processes at work in block Y above) *prior* to fuller democratisation of the central political system as such. What might be thought of as the contemporary Russian or Eastern European sequence, to an extent forced by external circumstances of a sort never present during the first climacteric, is illustrated in Chart 6 (80).

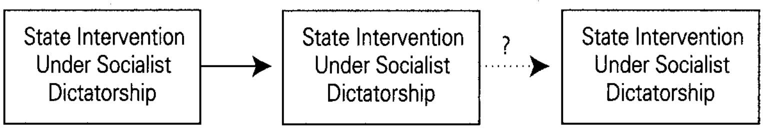


Chart 6. Political Punctuations, Markets and Industrialisation

This sequence does not seem to work and appears to have no historical precedents in the years since the initial industrial revolution of Britain. Yet it is mainly towards those nations which are relatively newly dynamic within the present climacteric (for instance, those with growing trade surpluses with the USA, such as China, Thailand or Malaysia) that *international* pressure for democratic reform joins with *internal* "middle class" pressures for reform (81). In our model, any resulting collapse of the industrialisation process, as has clearly occurred in Eastern Europe and at large within Russia, threatens to destroy the most recent technological and institutional gains, holds back the fuller emergence of internal forces for change (especially the rise of the middle classes more broadly) and removes the base from under the institutions of the scientific and technological enterprise. More importantly, the premature ejaculation of democratic forces may undermine the commercial integrations between the metropolitan centre and the new industrial winners (eg. today China is second only to Japan in its trade surpluses with the USA) which in the past have acted as one key influence in the movement away from authoritarianism in *both* the economic and the political systems of newly industrialising countries.

Conclusions

The style of presentation in this paper has permitted periodic summaries and estimations of position. These do not need to be repeated here. Clearly, there will be many readers who will instinctively dislike the style and level of argument. For instance, many historians of science or technology will be loath to reduce the notion of a support structure for national science and technology to the levels of the State, private enterprise and middle class demands, (e.g. as in Chart 5 above) (82). Truly, there is a vital global component to all science, and ideas transfer more readily and often more insidiously than do techniques. It is also true that in varied settings, technological development may run ahead of "scientific" development in any national setting, and that this may be especially the case during periods of significant industrial or commercial progress (83). Nevertheless, the historian who adopts an analytical approach does need to acknowledge the effect of two-way impacts of science and technology upon the industrialisation process and, in particular, the relations between knowledge, technique and institutions. The contribution of "science" (if such may be adequately isolated) during periods of rapid industrialisation remains problematic. However, it is *precisely* through periods of rapid change that the shape of things is determined. Within this, the State has played and does play a crucial role. Therefore, the historian who looks back on the development process and notes that full metropolitan membership is mainly composed of nations more or less democratic and more or less boasting free market ideologies (*never* free market policies in full) must be prepared to at least consider the problems of cause and effect, of interpretation and sequence. So-called free systems, including open and individualised systems of scientific research and technological innovation, generate growth within the metropolis, act as vehicles of transfer between the nations of the metropolis, and have demonstrated some successes in underdeveloped, non-metropolitan economic systems. But the question still remains as to how far they may have ever generated or been especially appropriate to that crucial conjunctural transformation wherein there is a change of status from periphery to metropolis.

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11) For good representations of institutionalist positions see many articles in the *Journal of Economic Issues*, the special issue of the *Economic Journal* (January 1991) and Warren J. Samuels, *Essays on the Economic Role of Government*, Vols. 1 and 2 (both London, 1992). For excellent historical studies of protoindustry and regionalism which consider market creation and the power of institutions see M. Berg (ed), *Markets and Manufacture in Early Industrial Europe* (London, Routledge, 1991).

12) Milton Friedman, *Free to Choose*, London, 1980, quotes p. 96, 333.

13) There is, of course, debate on the exact extent and effectiveness of Meiji State interventions. For a brief introduction see Ian Inkster, "Technology Transfer and Industrial Transformation: Interpretations of the Pattern of Economic Development circa 1870-1914", in Robert Fox (ed), *Technological Change*, Oxford, 1995 (forthcoming).

14) Karl Polanyi, *The Great Transformation*, Boston, 1944, 1985; Douglas North, "Institutions", *Journal of Economic Perspectives, 5* (1991); Douglas North, *Institutions, Institutional Change and Economic Performance* (Cambridge: Cambridge University Press, 1990).

15) W.J. Macpherson, *The Economic Development of Japan 1868-1941*, London, 1987, quote p. 57.

16) With reference to science and technology as such, the role of the eighteenth century British State has been underestimated. There emerged a loose but effective configuration between such direct arms of government as the Admiralty, the Board of Longitude, the Board of Agriculture, the Mint and the Board of Trade and such key institutions as the East India Company, the Royal Society, the Society of Arts and, at the end of the century, the Royal Institution, at a time when government was screening the "useful" sciences for solutions to problems of navigation, acclimatisation and naval supply.

17) David Hume, *Essays Moral, Political and Literary*, Edinburgh, 1741-2 (quotations from edition in *Works of David Hume*, XXXIII, London, 1903).

18) R. Watson, *Anecdotes of the Life of Richard Watson*, London, 1817, quote p. 276.

19) For contrasts see F. Haber, *The Chemical Industry during the Nineteenth Century*, Oxford, 1958; W.H.G. Armytage, *The Rise of the Technocrats, A Social History*, London, 1965; F. Rose, *Chemical Instruction in Germany and the Growth and Present Conditions of the German Chemical Industry*, Diplomatic and Consular Reports, London, 1901; Peter Alter, *The Reluctant Patron, Science and the State in Britain 1850-1920*, Oxford, 1987, and of course Pollard *op. cit.* (see reference 4 ch. 3).

20) *Nature*, 26 December 1901, p. 175.

21) *Nature*, 9 March 1911, p. 69-70; 23 February 1991, p. 63; *Board of Trade Journal*, 17 August 1911; see P. Lundgreen, B. Horn, W. Khron, G. Kuppers, P. Paslack, *Staatliche Forschung in Deutschland 1870-1980*, Frankfort, 1986.

22) *Nature*, 9 March 1911, p. 69-70; *British and Colonial Druggist*, January 1910, p. 6.

23) Thus the Imperial Chemical Institute was directly financed by the State and through the Association for the Protection of the Interests of the German Chemical Industry; government initiated the institution, private interests financed it thereafter: *Chemical Industries, 34* (1911), p. 588-89.

24) Haber, *op. cit.*, p. 126 forward.

25) *Ibid.*, p. 124-135; Rose, *op. cit.* (see reference 19).

26) Ian Inkster, "The Other Side of Meiji – Conflict and Conflict Management" in G. McCormack and Y. Sugimoto (eds), *The Japanese Trajectory: Modernisation and Beyond*, Cambridge, 1988, p. 107-28.

27) *Nichi Nichi Shimbun*, 2 October 1878; *Japan Weekly Mail*, 18 January 1879.

28) By the end of the outbreak in December 1879 cholera had claimed 96,660 deaths, out of a total number of cases of 164,229, with 21,714 still under treatment. The Tokyo Board of Health alone spent some 100,000 yen in sanitary measures.

29) *Japan Weekly Mail*, 16 August, p. 1076, 23 August, p. 1107, 30 August, p. 1177, 13 September, p. 1208, 18 October, p. 1384, 20 December, p. 1695, 1879.

30) E.O. Reischauer, *Japan, Past and Present*, London, 1964, quote p. 84.

31) *Japan Weekly Mail*, 24 September 1870, p. 462.

32) *Chügai Bukka Shimpö*, 3 October 1878, p. 2.

33) Which is not to say that foreign enterprise did not at times find ways to circumvent the prohibitions, usually through the financing of indigenous traders eg. mines might be financed indirectly through large loans in advance of delivery of minerals. At times the Japanese complained of "those foreigners who, notwithstanding the present prohibition, are purchasing, in the names of Japanese, Government bonds or holding immovable property, or under various pretexts are, in reality, assisting in mining works etc. Such cases are indeed beyond calculation" (*Chügai Bukka Shimpö* (Home and Foreign Commercial Progress) 3 October 1878, p. 3. See also Inkster, *op. cit.* (see reference 13).

34) *Ibid.*, (Inkster) and A. Kahan, "Capital Formation during the Period of Early Industrialisation in Russia 1890-1913", in P. Mathias and M.M. Postan (eds), *The Cambridge Economic History of Europe, VII*, part *2*, Cambridge, 1978, p. 265-307.

35) "Materially po istorii SSSR, VI: Dokumenty po istori monopolist-icheskogo Kapitalizma v Rossi" (Moscow 1959), p. 173-95, translated and reproduced in T.K. Von Laue, *Journal of Modern History, 26* (1954), p. 60-75. As the Minister responsible for finance and industry, Witte's reign dominated the 1890s (1892-1903). He was dismissed by the Tsar in 1903, recalled after the 1905 revolution as prime minister of an elected Duma, and dismissed as a liberal in 1906.

36) George Kamensky, "The Ironworks of the South of Russia", *The Engineer*, 20 September 1895, p. 293-95.

37) A. Vucinich, "Politics, Universities and Science" in T.G. Stavron (ed), *Russia Under the Last Tsar*, Minneapolis, 1969, p. 154-78.

38) J.R. Bartholomew, "Why Was There no Scientific Revolution in Tokugawa Japan?" *Japanese Studies in the History of Science, 15* (1976), p. 111-25.

39) M. Maruyama, *Studies in the Intellectual History of Tokugawa Japan*, Tokyo, 1974; Ian Inkster, "Science, Technology and Economic Development – Japanese Historical Experience in Context", *Annals of Science, 48* (1991), p. 545-63.

40) M. Yuasa, "The Growth of Scientific Communities in Japan", *Japanese Studies in the History of Science, 9* (1970); M. Yuasa, "The Scientific Revolution and the Age of Technology", *Journal of World History, 9* (1965); J. Bartholomew, *The Formation of Science in Japan*, New Haven and London, 1989.

41) Bartholomew, *Ibid.* and Ian Inkster, "Catching Up and Hanging On: The Formation of Science in Modern Japan", *Annals of Science, 47* (1990), p. 493-406.

42) Inkster, *ibid.*, quoting Bartholomew (p. 398).

43) "The Russian Iron Trade Crisis", *The Engineer*, 27 December 1901, p. 655-6.

44) "Why Japan is Victorious", *Nature, 72*, 8 June 1905, p. 128-9.

45) See Chapter 7 of Inkster, *op. cit.*, (see reference 3, (1991)).

46) K.M. Hobson, "The Military-Extraction Gap and the Wary Titan: The Fiscal-Sociology of British Defence Policy 1870-1913", *Journal of European Economic History, 22* (1993), p. 461-506.

47) See as an example Kozo Yamamurra, "Success Illgotten? The Role of Meiji Militarism in Japan's Technological Progress", *Journal of Economic History, 37* (1977), p. 113-33.

48) The story is, of course, far more complex than this: see Inkster, *op. cit.*, (reference 3, 1991), chapters 4 and 5.

49) For an excellent early account of government industries see T.C. Smith, *Political Change and Industrial Development in Japan: Government Enterprise 1868-80*, Stanford, 1955.

50) Koichi Emi, *Government Fiscal Activity and Economic Growth in Japan 1868-1960*, Tokyo, 1963; Koichi Emi, "Economic Development and Educational Investment in the Meiji Era", in M.J. Bowman *et al.* (eds), *Readings in the Economics of Education*, Paris, UNESCO, 1968.

51) Between 1880 and 1940 higher scientific and technical education increased fortyfold in student numbers, further technical and commercial education eightyfold.

52) "Iron and Steel Manufacture in Russia", *The Engineer*, 26 June 1891, p. 512.

53) H. Bauerman, "Iron and Steel at the Universal Exhibition, Paris, 1900", *The Engineer*, 2 November 1900, p. 448-50.

54) For earlier mining and metallurgy see W.L. Blackwell, *The Beginnings of Russian Industrialisation 1800-1860*, Princeton, 1968; T. Esper, "Industrial Serfdom and Metallurgical Technology in 19th Century Russia", *Technology and Culture, 23* (1982), p. 583-608.

55) For the essential features of the golden age see A. Van Dormel, *Bretton Woods: Birth of a Monetary System*, New York, 1978; W.M. Scammell, *The International Economy Since 1945*, 3nd edn., London, 1983; P. Armstrong *et al.*, *Capitalism Since World War II*, London, 1984.

56) Clearly a number of other NICs might be nominated as illustrating rapid growth during the second climacteric, such as Brazil, Turkey or Venezuela, all of which shared high rates of overall industrial growth and investment from the 1970s. For overviews see S.B. Lidner, *The Pacific Century*, Stanford, 1986; World Bank, *World Tables*, World Bank, The Johns Hopkins University Press, Baltimore, 1991.

57) Here we focus on the climacteric effects as relevant to new industrialisers. As dramatic are the institutional associations and repurcussions of relative decline in metropolitan leaders. For an excellent detailed introduction see B. Bellon and J. Niosi, *The Decline of the American Economy*, New York, 1988.

58) For overviews of NIC dynamism R. Holheinz and K.E. Calder, *The Eastasia Edge*, New York, 1982: J. Woronoff, *Asia's "Miracle" Economies*, Tokyo, 1986.

59) The President's Commission on Industrial Competitiveness, *Global Competition: The New Reality*, Washington DC, 1985; R.H. Hayes and W.Y. Abernathy, "Managing Our Way to Economic Decline", *Harvard Business Review, 58* (1990), p. 67-77.

60) R.A. Morse and R.J. Samuels (eds), *Getting America Ready for Japanese Science and Technology*, Washington DC, 1985; The Business Roundtable, *American Excellence in a World Economy*, New York, 1987.

61) M.L. Dortouzos *et al.* and the MIT Commission on Industrial Productivity, *Made in America: Regaining the Productive Edge*, Cambridge Mass., 1989.

62) Ian Inkster, "Made in America But Lost to Japan: Science, Technology and Economic Performance in the Two Capitalist Superpowers", *Social Studies of Science, 21* (1991), p. 157-78.

63) Andrea Boltho, *Japan, An Economic Survey 1953-1973*, London, 1975.

64) Most notably Sony's purchase of Columbia Pictures and Matsushita's purchase of MCA, owner of Universal Studios, and the 1992 bid by Nintendo to buy up the Seattle Mariners, an American major league baseball team.

65) Added to the flow of US aid was American liberalism towards NIC protectionist policy during the strategy of import substitution, the expanding US market for NIC manufactures and the stimulus to Asian NICs (especially Taiwan and S. Korea) of the Vietnam War.

66) Even prior to the 1973 OPEC oil crisis, commentators were identifying a "turning point" in the Japanese economy composed of several discrete elements: increased labour scarcity and capital surplus, problems of pollution, impacts on trade of yen revaluation and effects on productivity of "closing" the technological gap between Japan and the USA. Although such forces did have consequences within Japan, their external effects were also of importance, effects reduced in relative terms only by the unparalleled expansive effects of yen revaluation from 1985.

67) M. Goldsbrough, "Foreign Direct Investment in ASEAN: Its Sources and Structure", *Asian Economics, 61* (1987); T. Nakakita, "The Globalisation of Japanese Firms and its Influence on Japan's Trade and Developing Countries", *The Developing Economies, 31* (1988); papers by Yamashita and Phongpeichit in S. Yamashita (ed.), *Transfer of Japanese Technology and Management to the ASEAN Countries*, Tokyo, 1991.

68) UNESCO, *Statistical Yearbook 1986*, Paris 1986, from tables V-9 to V-117.

69) See K.Y. Edward Chen, *Hyper Growth in Asian Economies*, New York, 1979; Shirley W.Y. Kuo, *The Taiwanese Economy in Transition*, Boulder, 1983; Y.W. Rhee *et al.*, *Korea's Competitive Edge*, Washington, 1984.

70) H. Mutoh et al. (eds), *Industrial Policies for Pacific Economic Growth*, London, 1986.

71) Ian Inkster, "Education, Human Capital and Technical Change in Japan – A Sceptical Evaluation", *East Asia, 6* (1993), p. 99-111.

72) Ian Inkster, *Clever City: Japan, Australia and the Multifunctional Polis*, Sydney, 1991.

73) Woronoff, *op. cit.*, (see reference 58) chapter 11; see also chapters 1 and 7.

74) K. Nakamura, "Management Strategies and Changes in the Employment Structure of small-and-medium-sized Enterprises in Manufacturing Industry Under Technological Innovation in Japan" *East Asia, 6* (1993), p. 75-94..

75) For instance, W. Bello and S. Rosenfeld, *Dragons in Distress, Asia's Miracle Economies in Crisis*, London, 1992.

76) Special Issue, Adaptation and Transformation of Western Institutions in Meiji Japan, *The Developing Economies, XV* (1977).

77) See the discussion and references in Section 1 above.

78) Thus the attempts to establish "just in time", QC circles and *Kanban* systems into US and European enterprises in the 1980s and 1990s. Institutional transfer may take surprising and reverse-flow forms e.g. as early as the 1870s the US mathematician and university administrator J.D. Runkle (1822-92) founded the Lowell-shops after proposing that the Russian system of shop instruction should be introduced at the MIT.

79) Ian Inkster, "Relative Backwardness and Revolution; A Note on Marx, History and the Transition to Socialism", *Journal of Contemporary Asia, 22* (1992), p. 146-151.

80) For an excellent account of sequencing, similar to that used here, and a common-sense approach to China see W.H. Overholt, *China, the Next Economic Superpower,* London, 1993. See also, R. Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialisation,* Princeton, 1991; H. Genberg, "On the Sequencing of Reform in Eastern Europe", *IMF Working Paper* 91/93, International Monetary Fund, 1991; S. Howes and A. Bollard, "Economic Reform and Internationalisation: China and the Pacific Region", *Pacific Economic Papers,* 208, June 1992. Australia-Japan Research Centre, ANU, Canberra, 1992.

81) See David W.W. Chang, *China Under Deng Xiaoping,* London, 1988; M. Oksenberg *et al., Beijing Spring 1989,* Armonk, M.E. Sharpe, 1990; Liu Binyan, *China's Crises: China's Hope,* Cambridge Mass., 1990; F. Deyo (ed), *The Political Economy of the new Asian Industrialism,* Ithica, 1987.

82) Although see Inkster, *op. cit.,* (see reference 3), p. 89-130.

83) For one case study (Australia), Ian Inkster, "Intellectual Dependency and the Sources of Invention", *History of Technology, 12* (1990), p. 40-64; Jan Todd, "Science at the Periphery", *Annals of Science, 50* (1993), p. 33-58.

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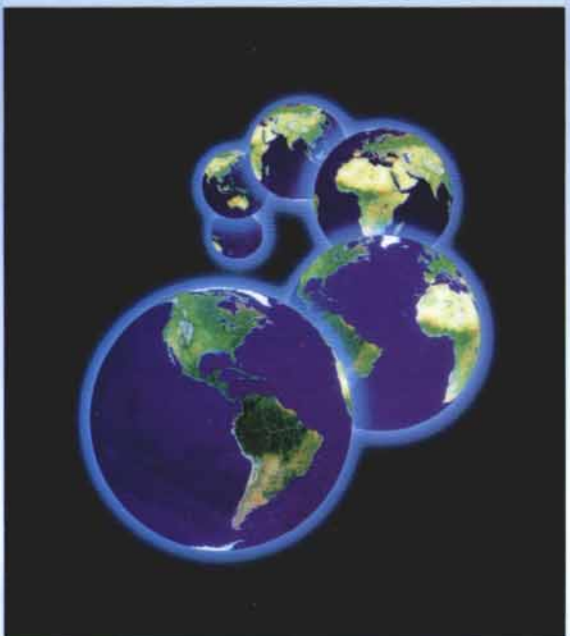

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