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Environmentally Sound Technology: Is Poland Overcoming Soviet-Type Learning Barriers?

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Introduction

Specific circumstances provide historic opportunities for Poland as recipient of Western environmental aid in pursuit of sustainable, environmentally sound technology (EST) development. First of all, the somewhat paradoxical effects of the membership in the Soviet bloc on environmental problems present the Polish reformers with important opportunities for both environmentally-oriented modernisation and nature conservation. Secondly, the technological revolution on a global scale concurrently with the Velvet Revolution in Central and Eastern Europe (CEE) provides new opportunities for assimilation of Western technology as well as institutional learning in CEE. Thirdly, new environmentally sound technologies are increasingly available for transfers, and may therefore help Poland, as well as CEE national systems of innovation in general, to implement EST polices. In addition, there are also opportunities for social science to integrate research approaches as CEE economies transform. A central question is if Poland is overcoming prevailing CEE learning barriers in the assimilation of EST, something this paper proposes to be studied integrating national systems of innovation, technology assimilation, and interdependence approaches relying on existing evolutionary theory of technological change.[1] The thrust of the paper is to suggest an integrated assimilation analysis for assessment of Polish environmentally sound technological learning.

The fact is that Poland has a discouraging record of assimilating Western technology. The economic results of vast technology transfers in the 1970s were drastically reduced by delays in the utilization of purchased technology, in the construction of plants, in the installation of imported machines and equipment and in the achievement of the full scale of production (Fallenbuchl 1983). Similar results had been reported about the USSR (Hanson and Hill 1979). There did exist a Soviet-type pattern of problematic technology assimilation which required a reform "to remove harmful systemic barriers and obstacles to innovation" (Fallenbuchl, p. 87).

As states Lundvall (1992): "Product or process technologies borrowed from abroad do not automatically fit into new institutional set-ups" (p. 311). Accommodation of the receiving institutional system, 'institutional learning', not only innovations themselves, becomes necessary. The problem of the Soviet-type system was its rigidity - the reluctance to change was too strong within the regime and the industrial leadership. The problem now, in the process of CEE transformation is that, unless Soviet-type barriers to learning are being removed, current opportunities will pass unexploited, including the potential of comprehensive Polish introduction of EST in technological modernisation.

Windows of Opportunity

A Paradox of Post-Communist Environmental Problems

Membership in the Eastern bloc implied great changes in Poland. In the first two decades of the Soviet-type system, heavy industry plants, such as a whole metallurgical industry, was built almost from scratch, and engineering and shipbuilding industries were rapidly developed. Coal extraction and electrical power generation increased manifold on the basis of huge investments in the 1948-70 period. Smoke-spewing stacks of newly erected steelworks and power stations stood as signs of economic and technological success of the Soviet-type system. These 'successes' came at great

[1] In particular propositions on global and evolutionary technological change, such as Perez (1983 and 1985), Dosi (1984), Freeman (1984) Sahal (1985) and Nelson (1996),which differ from neo-classical approaches in economics by considering heuristic systems characteristics of technology and economy, the importance of learning and institutional factors.

environmental costs, however. Gigantic steelworks, chemical plants and factories formed the 'edifice of the Soviet model of growth' (Nowicki 1993).

The state of the natural environment in Poland has been influenced by a joint impact of a whole variety of factors, such as existing energy and mineral resources, previous and current industrial policies, the Soviet-type system of industrial management, ideology and general Soviet bloc history. In the period of Soviet bloc membership, natural resources, such as water, air, forests and mineral deposits had no prices and no value according to official ideology. The State alone had property rights to all natural resources and the command system of economic management, in which the authorities reserve the right of detailed setting of objectives and means of economic activity, obviously contributed to a 'nature-intensive pattern of growth'. Doctrinal reasons, such as the Stalinist policy of forced industrialisation, together with the raw material base, determined this nature-intensive growth pattern (Lubinski 1992).

Environmental problems are for many years to come marked by this legacy. Current surveys and official statistics of the situation after the velvet revolution reveal Poland's serious environmental problems in terms of air and water pollution, waste management and nature conservation (OECD 1995, Zylicz 1994, UNEP 1993, Nowicki 1993, Lubinski 1992). Air pollution is still largely the result of the outmoded industrial technologies and the use of highly polluting fuels. Poland particularly suffers from high levels of SOx, NOx and carbon dioxide. Damage is often concentrated in a number of pollution 'hotspots' in which technology is highly obsolete. The major source of pollution is the energy sector, i.e. from the heavy reliance on coal and lignite. Large emissions of air pollutants are attributed to the high energy-intensity of industrial production, a high share of fossil fuels with a high sulphur content, poor or lacking pollution-reducing devices and obsolete manufacturing technologies. Mobile sources, i.e. transportation, yet play a minor role. (Transportation will, however, be an increasing problem or air pollution as the number of cars per capita will approach OECD levels.)

Poland is also a significant contributor to global warming. According to the latest national and OECD statistics, it had the sixth highest level of CO2 emissions in Europe. Though per-capita emissions are only slightly higher than the OECD European average, emissions per unit of GDP are twice that of the highest OECD emitters. CO2 emissions have decreased since the late 1980s, due in part to the economic slowdown following the collapse of the Soviet-type economy in 1989. The economy is growing again, but the energy efficiency is also improving.

In terms of water resources, Poland is one of the most scarcely endowed countries in Europe and available water per capita is one of the lowest. Poland uses the water it has in a very inefficient way according to studies, consuming two-three times as much water per unit GDP as the OECD countries. Much of the water is heavily polluted, largely due to poor or non-existent waste water treatment. Again, closing plants will reduce emissions and modernisation will help improve reductions of pollutants in waste water.

Poland is one of Europe's largest sources of industrial waste both in absolute terms and as a function of GDP. Almost all waste goes to landfills without separation. Hazardous waste is generally not being treated and handled, thus providing a case of great opportunities for modern environmental techniques and management.

Industrial activities have thus lead to devastating environmental results; 27 areas are described as "ecological hazard zones". Paradoxically, however, more than a quarter of the total Polish territory is in a natural or close to natural state. Species diversity has remained fairly constant, though numbers and distribution have seriously declined. Vistula is one of the largest sources of pollution for the Baltic Sea due to industrial waste let out in the later stretches passing south-east and Central Poland’s industrial area. Yet the Vistula and Warta rivers have the last large riparian stretches in Europe. The last primeval lowland mixed forest in Europe, the Bialowieza, dates back to 8,000 BC and is the only remaining example of the original forests which once covered most of Europe. Now much of the forest is threatened by selective logging and even clear-cutting.

The paradox underlying Polish - and generally post-communist countries’- environmental problems is the legacy of socialist inefficiency - both in energy resource use, environmental protection but also in the comprehensive exploitation of nature, including forests. Soviet-type inefficiency both has had extremely hazardous effects and protected diversity. This is perhaps particularly so in Poland, the formerly Eastern bloc country that still had privatised and small scale agriculture.

The paradox is further exemplified by the fact that the Polish ‘inefficient’ (small-scale and low-mechanised) agriculture helped preserve diversity of species because of small plough-fields, uncovered ditches, greater crop diversity and more rotation, relatively lower reliance on mineral fertilisers and an amount of horses (rather than Soviet tractors that would press the soil hard, thereby increasing fertiliser run-offs) and cattle that corresponded to the capacity of the soil area’s ability to absorb manure. I was in such a ‘pre-industrial’ agricultural environment - in Poland, and to a lesser extent in Eastern Germany and the Baltic Republics - that a diversity of species was preserved, while at the same time it was being threatened and species extinct in the fields of neighbouring West Germany, Denmark, Sweden and Finland. Poland has in the last centuries lost 15 species, including 3 mammals, 11 birds and 1 fish species, while the corresponding figure for Germany is 28 species; 7 mammals, 19 birds and 2 fishes (Zylicz 1994). All 17 national parks in Poland are on the IUCN list, three of them are included by UNESCO in a network of biosphere reserves representing typical, well preserved examples of the world’s ecosystems.

The country can be considered the pioneer of post-communism. The first post-communist government was formed there, the Mazowiecki government of August 8, 1989, which included the minister of finance and 'the architect of the Polish reform', Leszek Balcerowicz. Poland has also been among the most successful country of Central and Eastern Europe in implementing market economic ideas. The newly adopted market economic principles in Eastern Europe have been considered panaceas, among influential actors, for remedying environmental degradation as one legacy of socialism. Leszek Balcerowicz concludes in a recent chronicle (1996):

> “Radical economic reform proved capable of sharply reducing environmental pollution. For example, emissions of most air pollutants in the environmental hot-spots in Poland declined by about 50% thanks to industrial restructuring, reduced energy intensity and much more strongly enforced environmental regulation. The economic-ecological trajectory produced by radical reform is much better than the one which Poland, and other radical reformers, would have travelled had socialism continued”. (1996).

True, bankruptcies and close downs of inefficient production units based on obsolete technologies of socialist origin will help in reducing environmental pollution - and that has already happened. This is the positive effect of a Polish government programme which encouraged ‘creative destruction’, ‘forgetting’ and ‘unlearning’ processes. According to a review of the top 80 ‘hotspots’, 7 plants have been shut down and 22 were restructured toward more environmentally friendly profiles. Another 20 plants significantly reduced their emissions by installing abatement equipment. Nevertheless, several large steel mills did almost nothing, and one power plant even increased its emissions slightly (Zylicz 1994). Sulphur emissions were reduced from 2,050,000 tons in 1980 to “only” 1,498,000 tons in 1992, nitrogen oxide emission from 1,500,000 tons to 1,250,000 tons the same years (Acid News).

The paradox of environmental degradation under socialism now leads to a concern with the ecological effects of the velvet revolution. Environmentally sound development requires the 'hot spots' being modernised or closed down. But as post-communist countries undergo a political, economic and technological transformation processes, the still unexploited zones must be protected against a economically more efficient, and therefore geographically more comprehensive pattern of resource use which may have devastating effects for environmental protection and rehabilitation as well as nature conservation and biological diversity. European Commissioner on Environment Ritt Bjerregaard after a visit to Poland in February 1996, while praising the host country for curbing pollution, also emphasised the need for Poland to poise itself against damage stemming from booming economic growth.

'Technological Revolution' and West-East Technology Transfers

Existing theories of global and evolutionary technological change, such as those suggested by Perez (1983 and 1985), Dosi (1984), Freeman (1984) Sahal (1985) and Nelson and Pack (1996), provide some interesting new perspectives on international transfers of technology, notably West-East transfers. East European patterns of technology acquisitions must be seen as part of a specific geopolitical situation created within the CMEA (Comecon) region. Since environmental problems are related to specific technological systems, a background to environmental degradation must include references to major technology shifts based on generation, acquisition and international diffusion patterns. Freeman and Perez (1988) introduce the interpretation of long 'Kondratieff waves' as longer-term cycles or trajectories of comprehensively intertwined technological systems which historically shift as a result of 'technological revolutions'. At the global level of technological change, they characterise the last 'information and communication Kondratieff' (1980/90-) as one based on microelectronics, where main 'carrier branches' are computers, electronic capital goods, software, telecommunications equipment, data bank, information services, etc. The fourth 'Fordist mass production Kondratieff' (1930/40-1980/90s) rather had 'carrier branches' in automobiles trucks, tractors, process plant, synthetic materials and petrochemicals, with energy, especially oil as key factor. The previous third 'electrical and heavy engineering Kondratieff' (1880/1890-1930/40) had steel as key factor and 'carrier branches' in electrical engineering, electrical machinery, heavy engineering, steel ships, heavy chemicals electricity supply and distribution.

If such a notion of global technological change is accepted, it is suggested that waves of technologies diffuse transnationally depending on national systems' ability to absorb and assimilate the technologies of these waves. Perez and Soete (1988) give examples of successful assimilation of Japan and South Korea, capitalising on the windows of opportunity for 'late industrialisers' depending on specific conditions for undertaking the task of assimilating foreign technologies. 'Entry costs' involve investments in much more than the fixed investments, but also in costs for scientific and technical knowledge and experience, not to speak of the cost of compensating for lack of externalities. Government regulations, standards, taxes, subsidies, tariffs, policies and laws, trade-union practices, the financial system, values or even language influence comparative cost levels of various locations. Nelson and Pack (1996) argues against the 'accumulation' theories, which stress the role of investments as sole forces behind growth in economies moving 'along their production functions', that specific learning processes must be explanators for growth in 'miracle' economies such as Korea and Taiwan.

Perez (1983) suggests, from a perspective that can be argued to follow Friedrich List rather than Adam Smith, that institutional changes interact with, or even determine, the major changes of technological breakthroughs. We can observe, according to her, socio-economic transformations as the critical factor later appearing in economic figures and interpreted as Kondratiev waves:

> "we postulate that Kondratiev's *long* waves are not a strictly economic phenomenon, but rather the manifestation, measurable in economic terms, of the harmonious or disharmonious behaviour of the *total* socio-economic and institutional system (on the national and international levels)."

Seen in a longer historic perspective, the 'Velvet revolution' in the Soviet and East European region in 1989-91 in time approximates a 'technological revolution' that led, in other industrialised countries, to massive global introduction of semi conductor technology which required and provided vast and increasingly more liberal information flows (Perez 1983 and Freeman 1984, both 1988). In fact, it can be argued that the latter 'revolution' was one of the major causes of the former.

The Soviet-type development model had been based on 'extensive', rather than 'intensive' growth (Nove 1992), i.e. increasing volumes of output had been the result of increasing resource use rather than increased efficiency. The stagnation period under Brezhnev was a crisis of inefficiency (Bialer 1984) and Soviet innovation rates were low despite attempts at keeping pace with Western technology through massive transfers financed by the oil export revenues. The more high-technology related (microelectronics and semi conductor technology) this race with the OECD and NATO countries became, the more apparent the weaknesses of the Soviet-type technology capabilities proved to be. All resources were therefore mobilised to provide the priority sectors with massive support, while low-priority sectors were generally given close to nil in terms of technology.

In military-industrial production, were conditions were the best, there were still great problems in applying the old models of reverse engineering, adaptation and replication to semi conductor technology. The smaller and the more complex the micro chips, and the more demanding the equipment and conditions for their production, the more difficult and the more time consuming it was for Soviet engineers to "invent the bicycle again", as the Russian expression goes. Effective Western embargoes on high and dual-use technology forced the Soviet and East European institutes, academies and 'research-production enterprises' to increasingly rely on clandestine imports. As the innovation rates and speed increased in Western and (south-east Asian) semi-conductor industry, the old innovation pattern in the Soviet bloc proved inappropriate as vehicle for technological advance. Most probably, the "Star Wars" program launched by Reagan made Soviet military-industrial leaders definitely realise they already lost the race.

In the Soviet Union the basic pattern, typical for Russia since at least Peter the Great, remained; isolated waves of technology imports for specific domestic (notably military) programs. Lenin advocated a Soviet application of Taylorism under the label 'Scientific Organisation of Work' (Nautchnaya Organizatsia Truda). Later Stalin opened the door for temporary inflows of technology in the first five-year plan 1929-33 (he closed it in the second) of which some eventually helped 'modernise' the satellite states of Central and Eastern Europe after the War. Khrushchev encouraged imports of fertiliser and other chemical plant in the 1960s. Brezhnev and Kosygin supported rather massive technology import programmes pioneered by the Fiat auto-plant agreement and the Kamaz truck plant in the 1960s to 1970s. Resources were never sufficient to make general and all-embracing imports, however, and Soviet indigenous innovation was slow and selective.

This is why the 'technological style' or 'paradigm' continuously improved and refined in the Western world was petrified in its crude early fashions in the Soviet Union and later diffused, for political reasons, in Central and Eastern Europe. The environmentally devastating Lenin steel plant in Nowa Huta in southern Poland was built from Soviet adapted technology dating back to early Stalinist imports of Western technology. In that sense Western technology, via the Soviet Union, have been the reason for much of the gravest environmental damages in the CEE and former Soviet Union.

The industrial and technological background to the Polish technology acquisition initiative in the 1970s was the obsolete Soviet type structure:

> "During the industrialization drive in Eastern Europe at the beginning of the 1950s attempts were made to construct a comprehensive multibranch industrial structure based on priorities given to heavy industry, import substitution and the long-run objective of self-sufficiency. Too a considerable extent this was an imitation of the Soviet industrial structure that had been built during the 1930s. It gave priority to those branches of industry that (...) belong to the classic 19th century type of industrialisation: the iron and steel, heavy machinery and heavy chemical industries. On the other hand, insufficient consideration was given to the 'new' branches being born at the time in advanced countries." (Fallenbuchl 1983)

When, concludes Fallenbuchl, the structure was imitated throughout Eastern Europe, the technological lag which already applied to Soviet industry, was further magnified. The full extent of the technological gap between the West and Eastern Europe was beginning to be realised.

A sudden acceleration in technology transfers to Poland occurred in the early 1970s, when there was a dramatic acceleration in technology transfer and capital borrowing from the West. Although the inflow declined in the second half of the 1970s, the decade differs considerably in this respect from the entire period 1945-70 (Fallenbuchl 1983).

The acceleration in technology transfer at the beginning of the 1970s was a component part of the so called 'new development strategy' and its decline at the end of the decade was closely connected with the failure of that strategy. The background of the initiated strategy was the growing awareness in Poland, as in other Eastern bloc countries, that it was necessary to modernise existing production capacities but also change the industrial structure, to increase expenditures on development of pure and applied science on R & D, and to implement some systemic reforms.

The planners expected that with the help of Western credits and imported Western technology there would be a rapid expansion in the production of modern, highly sophisticated and efficiently produced commodities. These goods would be produced in new or modernised plants, utilising the most modern Western machines, according to the Western standards and, in some cases, on the basis of Western licenses or under industrial co-operation arrangements with Western firms. The hope was to increase exports to western markets in order to repay debts.

Industrial co-operation links between Polish and Western enterprises thus appeared already from the mid 1960s, i.e. at the time the USSR also started its reliance on Western technology in some types of production (notably chemicals). In the Polish case, 23 industrial co-operation projects involved the production of some parts or elements in accordance with the specifications supplied by Western firms. A few agreements helped to establish, modernise or expand entire branches of industry. The agreement between H. Cegielski in Poznan and Sulzer in Switzerland established production of marine engines under a licence that led to export co-operation and was decisive for the expansion of shipbuilding efforts in Poland. An agreement with Fiat in Italy, signed in 1965 (concurrently with the Soviet-Fiat deal) involved the production of Fiat 125p in Poland, export of the product and parts to other countries, co-operation in transportation, servicing, supply of parts, etc. This agreement not only had a fundamental importance for the modernisation and expansion of the Polish automobile industry, but it has induced industrial co-operation with other Western firms, such as Bosch and Westinghouse for the production of various component parts. It has also created a basis for co-operation with the Soviet Union and Yugoslavia in the automotive industry.

During the period 1969-67 about 200 agreements were signed with Western firms, predominantly West German. A majority only involved simple forms of co-operation, but again, a limited number had significant importance for the Polish industry. Co-operation in the production of concrete pumps and mixers with Stetter (Germany), cranes with Jones (UK), and various types of metal working machines with Waldrich and Weway (Germany) involved some important transfers. A governmental decree in 1971 on industrial co-operation was intended to spur this type of transfers.

In the first half of the 1970s, the most important co-operation agreements with West European firms were the new or continued agreements with Fiat in Italy (the new Fiat 126p car), Berliet in France (buses), Steyer-Daimler-Puch in Austria (trucks), Massey-Ferguson-Parkins in UK (agricultural tractors), Voest Alpine in Switzerland (heavy industry), Menck in Germany (hydraulic excavators), Kockums in Sweden (dumpers), Siemens in Germany (presses), AEG Telefunken in Germany (electronics), Creusot in France (metallurgy), Sulzer in Switzerland (marine engines) and Stetter in Germany (concrete technology).

At that time, US large corporations entered with long-term Polish contracts. They included agreements with Clark Equipment to produce heavy duty drive axles for wheeled construction machines and mobile cranes (1972), International Harvester to produce crawler tractors (1972), Singer to produce sewing machines (1973), Honeywell for the production of industrial process control system (1973) and electronic transmitters (1974), and Corning Glass and RCA to produce component parts for colour television tubes (1976) (Fallenbuchl 1983).

The first observation to make from the Perez-Freeman periodisation of technological waves is that Polish technology acquisitions, because of geopolitical reasons, mirrored the Soviet large acquisition waves, which occurred in the last decade of each Kondratieff.[2] Thus, The USSR, as well as Poland, imported massively of the last decade of the fourth Fordist Kondratiev, i.e. in the 1970s, the period of west-east détente. Poland acquired much of the technology in the post-war period from the transfers made to the USSR during the New Economic Policy period and up to the end of the first five-year plan (1920s-1933/34).[3] The Polish transfers follow the pattern of steel production and heavy engineering in the 1950s, ‘second hand’ from the transfers made by the USSR in the 1930s, but turn to substantially more ‘modern’ (automotive, petroleum-based etc.) technologies in the 1970s.

Serious difficulties started to appear in the Polish economy as early as 1974, however. The new development strategy did not bring the expected results. Imported capital goods could not be absorbed and many machines were left un-installed. The priority allocations to investment, imported machines and licenses to sectors which could not become profitable exporters, but to the contrary, induced additional imports of fuels, material and parts, created balance-of-payment pressures. Transfer of technology which had been expected to play a key role in the new development strategy led to a hard currency debt crisis and serious internal and external unbalances. Concludes Fallenbuchl: “the main reason for the collapse of the ‘new development

[2] This is probably not a coincidence, but has never been analysed in detail.
[3] I would even go so far as to say that the Russian acquisitions before that actually coincided with the industrialisation in the 1880s to 1890s, but that is for economic historians to study. I have personally talked to Mr Morgun, minister of environment of the USSR in the 1980s, who described the environmental situation at a plant in the Volga region that emitted huge amounts of various chemicals into the Volga river. The plant was erected by a French firm in the 1880s, and was still used more or less without any modernisation..

strategy' was that it was simply too difficult to effect with a basically unchanged economic system. It was because of the existence of systemic obstacles that the transfer of technology was unable to bring about the expected results". Obviously Perez and Soete are right when they state that generally the success of "[t]he use of foreign, imported technology as an 'industrialisation' short cut depends on having the required conditions to undertake the difficult and complex process involved in its effective assimilation" (1988 p. 463).

Exports to the West as consequence of these plant transfers never grew as anticipated and balance-of-payment difficulties forced the planners to cut the investment programme. For that reason work on 49 big projects was stopped and un-installed plant increased considerably in the late 1970s and early 1980. The rate of the national income declined from one year to another and became negative for the first time in 1979. Unused production capacity, including the imported machinery from the West, appeared. Unable to expand exports and facing foreign indebtedness, planners introduced drastic reductions in imports, especially from the West.

However, as a result of the investment drive in the early 1970s the import-intensity of industrial production had increased even further. Leading export commodities, such as ships, heavy machines, railway rolling stock had a high import content. Instead of a gradual reduction, then, the deficit in trade with Western countries would further interrupt the investment projects and their efficient application. The new strategy thus had increased import-intensity of production more rapidly than the ability of the economy to earn enough foreign currency to repay the credits which had been obtained for the transfer and to finance the increased import level necessary for current production needs.

Difficulties in foreign trade and directly related shortages of materials aggravated the crisis in the second quarter of 1980. In June, the plan for the second half of the year attempted an improvement of the balance of trade at the cost of a further deterioration of in supply for the domestic market. The wave of strikes in August and September forced another change in the party and government leadership. An independent labour union 'Solidarity" and subsequently a labour union of individual farmers 'Rural Solidarity' were established. Liberalisation was taking place and the party and government was undergoing several changes (Fallenbuchl 1983).

There was a still persistent current account deficit for transactions in convertible currencies at the end of 1980, diminishing the possibilities of larger technology transfer programs. Average Polish capital was therefore getting increasingly obsolete in the 1980s, both in absolute and comparative terms (vs. both CEE and FRG, see fig).

Table 1. Age Structure of Equipment in Polish Industry 1975-1988 (Share of Assets Under Five Years of Age, Percent)

	1975	*1980*	*1985*	*1988*
Poland	42	35	17	19
Czechoslovakia	31	32	25	23
GDR	30	30	26	29
Hungary	41	41	28	29
FRG	n.a.	39	n.a.	40

Source: OECD 1992

There was an increasing East-West divergence in technological age the closer the eve of the Velvet revolution when CMEA countries and FRG are compared. There is also an increasing divergence within CMEA, with Poland as the country suffering most from obsolete technology. Poland limps behind, as is shown in the table, largely because of passiveness in the 1980-1985 period.

Poland as National System Learning EST

When the ‘national systems of innovation” (NSI) approach was introduced in the 1980s as model and conceptual framework for studies of national-level capabilities for technological change, the focus was made on industrial nations in the West (Freeman 1987, Lundvall 1988, Nelson 1988). At that time, Lundvall, in focusing on the process of learning in “a modern industrial society (capitalist or socialist)” (p. 349), concluded from a study of innovations in the Soviet Union (Amann and Cooper 1982), that “user-producer interaction seems to be a major problem in the ‘real existing socialist countries’ (p. 351 in Lundvall 1988). This (under)statement by one of the founders of the NSI approach points to the fact that, since the NSI approach was introduced by scientists involved in studies of industrialised Western countries at the time when command economies still existed in Europe and since these countries never exhibited exciting technological learning patterns, no ‘generic’ NSI studies were made of Soviet bloc countries. Only after the Velvet revolution, there is a growing interest in NSI studies of post-communist nations (Radosevic forthcoming). The NSI research community was for some reason more interested in why some nations learned more quickly than others than asking why there is a *variance* in NSI learning curves (and why command or ‘planned’ economies almost never learned).

Relying on region-specific literature, in particular assimilation approaches to the analysis of innovation processes in the USSR on the basis of Western technology as applied by Hanson and Hill (1979) and approaches to learning in organisations, such as Argyris (1982) and Hindman and Reichers (1987), my study of Soviet acquisitions of Western, in particular Swedish complete plant technology (1989) proposed some conceptualisations and methodologies for an assimilation approach based on similar assumptions and resulting in similar concepts as the NSI. Interestingly Nelson and Pack recently (1996) advocated an assimilation approach which takes proper account of national learning processes in ‘taking onboard and mastering’ new technologies.

The first assumption made by Lundvall in 1992 (Lundvall ed.), “that the most fundamental resource in modern history is knowledge and, accordingly, that the most important process is learning” has much in common with the rationale for combining technology assimilation approaches (such as Hanson and Hill 1979) with existing theory of organisational learning (such as Argyris 1982 and Hindman and Reichers 1987). Lundvall’s second assumption, “that learning is predominantly an interactive and, therefore, a socially embedded process which cannot be understood without taking into consideration its institutional and cultural context” fits into the assumptions of organisational theory of learning as well as studies of technological change. Sahal, for example, in 1985 makes the statement that ‘technology both shapes its socio-economic environment and is in turn shaped by it. Neither is a sole determinant of the other. The two co-determine each other’.

This is not mentioned to challenge the validity of any particular NSI approach, but on the contrary to confirm the significance of the NSI approach by giving examples from other disciplines in which learning processes have been studied and found relevant to the understanding of development at various levels of social organisations. It is also mentioned as a source for further conceptualisation that may be integrated with the NSI approach.

In particular, the central theme in the Lundvall *et al.* approach, the "fundamental interdependence between technologies and institutions" (p. 311, Dalum, Johnson, Lundvall in Lundvall 1992) somehow correlates with the interaction between assimilation of technology and the national accommodation (of institutions and routines) to such assimilation. I fully agree with Lundvall that "when technological innovations are diffused across national borders, adaptations are usually necessary: either parts of the receiving institutional system [which Lundvall et. al (1992) call 'institutional learning', Nelson (1982) calls 'mutation of routines' and I would call 'accommodation'- M.S.], or the innovation itself (or perhaps both), have to adapt. Learning becomes an extension of borrowing [which I prefer to call 'assimilation' - M.S.]. Borrowing becomes a part of learning" (p. 312 and Sandberg 1989).

However, there is one important difference in emphasis between 'technological learning' and 'technological assimilation'; 'learning' as concept assumes the existence of indigenous sources of learning which are relying only partly on the inflow and assimilation of foreign knowledge, while 'assimilation' assumes foreign knowledge as a basis on which indigenous learning occurs. There is thus a difference in perspective and emphasis; focus on indigenous learning including assimilation of foreign technologies or focus on assimilation of foreign technologies in indigenous learning. Given the stagnation in innovations system in the Soviet bloc, the assimilation perspective was natural. Given the focus on highly innovative systems, the attention of the NSI approach naturally focused on learning.

Another distinction may be made, depending on how the Lundvall et al. approach is interpreted. It is somewhat unclear, whether their concept 'learning' embraces two or three processes in interaction: technological learning (at firm level only?) and institutional learning (at national level only?), and/or if they are interdependent components of a national systems learning process. It is somehow confusing to use the term 'learning' for all these three processes (which I preferred to call assimilation, accommodations and adaptation/learning.)

I think this confusion is a result of multi-level thinking not explicitly introduced into the notion of learning in relation to the NSI approach. Learning, as well as assimilation and accommodation must relate to a clearly stated level of social organisation, whether national systems, organisations, such as firms, or at the international systems level. This is crucial, since the understanding of one system does not necessarily mean the understanding of the systems of other levels. The levels work much like Chinese boxes; learning at a lower level implies the learning in higher. But knowledge about learning in a smaller box does not mean the understanding of the learning in the larger. This is why, in understanding one national system of innovation, and its ability to assimilate foreign technologies, we need to propose some additional tools for understanding the logic of the larger system within which the national system operates.

The Asymmetry of Global Technological Interdependence

"National specificity" argue Dalum *et al.* (in Lundvall ed. 1992), "remains important and appear to bear a relation to the capacity to produce, acquire, adopt and use technology" (p. 296) Pivotal to this approach we find the "fundamental interdependence between technology and institutions. Technology (...) is embedded in an institutional set-up" (p. 311, Dalum *et al.* in Lundvall ed. 1992). This notion of interdependence between technologies and institutions is valid on all social levels, I would argue, and implies, in combination with existing theories of global technological learning, that the 'Kondratiev-type' technological waves, suggested by Perez (1983 and 1985, with Freeman 1988), on international level interact with institutions which, following Keohane and Nye's *Power and Interdependence* (1972), constitute 'international regimes'. In absence of a 'supra-national system' of government and in contrast to an non-regime or anarchic situation at international level, there are ‘international regimes’ consisting of "networks of rules, norms and procedures", i.e. "sets of governing arrangements" (p.19).

"The first premise", argue Keohane and Nye (p. 40), "is that technological change and increases in economic interdependence will make existing international regimes obsolete." This correlates to Perez' (1983) notion of institutional changes interacting with the major changes of technological breakthroughs - at both international and national level.

Freeman (1992) suggest that there are three sets of constraints to technological choice (three 'selection environments'): (1) the natural environment, (2) the built environment and (3) the institutional environment. In this context it seems obvious we have to qualify his proposition to be valid on multiple levels. National systems select trajectories on the basis of national and global or international constraints, just as corporations act within limits to choice of local, national and global or international character.

In the Polish case we find a growing number of international regime constraints to technological choice on national level. With the Brundtland Commission, its report *Our Common Future* (1987) and the Rio Conference 1992, guidelines had been set up for governments' policies and legislation as well as bases for a new international regime, *Agenda 21* and *the Tokyo Declaration*. Poland is a part of the UNCED process and has committed to implementing the Rio Declaration on environment and development. It is also a member of the UN Commission on Sustainable Development and recently submitted a national report on implementation of the Agenda 21. Poland also has ratified the Montreal Protocol on Substances which Deplete the Ozone Layer and is expected to ratify the London and Copenhagen amendments shortly. It has ratified the Framework Convention on Climate Change and is expected to ratify the Convention on Biodiversity.

In the European context, the European Union is aiding Poland in national integration as an effect of the 1991 signing of a "European Agreement to Associate the European Communities and its Member States with Poland". In a Baltic Sea region context, Poland has since 1989 joined many bilateral and regional agreements to reduce air and water pollution. Agreements are now in effect with all neighbouring states. An International Commission for the Protection of Oder River Against Pollution has been established, and the Baltic Sea Environmental Action Programme of 1992 has the purpose of restoring the Baltic through support to development of legislation, economic initiatives and local financing. All together, these treaties, agreements, commissions and programmes provide a "network of rules, norms and procedures" of an international regime, thereby setting "constraints to technological choice".

The emerging international regime on sustainable and environmentally sound development has roots in technology policy studies. *Limits to Growth* (1972) provoked a world-wide public debate, but also a study (Freeman and Jahoda 1978) at Science Policy Research Unit at Sussex University which came to the conclusion that growth should and could continue into the twenty-first century on two condition: that "a different path of world development (i.e. what came to be called ‘sustainable development’)" and "that environmental objectives were given a high priority in the work of industrial, university and government laboratories. This orientation would be needed to assure the rate and direction of technical change necessary to achieve the first objective (sustainable development) (Freeman 1992b)." A later, revised version of the MIT study was then published (1992), amending the models and envisaging the possibility of a much more optimistic scenario.

The replacement of old buildings, plant and machinery with environmentally sound designs is a very prolonged process. In fact this process would probably reflect the waves in technological style referred to above and its implications for investment waves. We have (yet) a very abstract and tentative understanding of environmentally sound technologies (EST) in the context of the global and transnational (firm-level) diffusion of technologies, technological systems and radical innovations. Agenda 21 defines EST as technologies that “protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes.” But they also cover "end of the pipe" technologies for “treatment of pollution after it has been generated.” In fact EST are “not just individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organisational and managerial procedures” (Agenda 21, article 34). This is thus a broader definition than, for example the ‘cleaner technology’ Kemp (1993) defines as “all techniques, processes, and products that avoids or diminish environmental damage and/or the usage of raw materials, natural resources, and energy”. EST rather correlates with ‘clean’ and ‘cleaning’ technologies taken together (p. 81).

Aid agencies are governmental authorities are of national or international nature. Seen from that perspective, aid is an international activity. Yet the projects are rather transnational, since technologies are (mostly) transferred from sub-national level organisations, such as firms, to (mostly) sub-national level end-users of that technology. Such international and transnational relationships taken together are often described in terms of what Keohane and Nye (1977) called ‘interdependence’:

> “Interdependence in world politics refers to situations characterised by reciprocal effects among countries or among actors in different countries. These effects often result from international transactions - flows of money, goods, people, and messages across international boundaries. (p.8-9)
>
> We must also be careful not to define interdependence entirely in terms of situations of *evenly balanced* mutual dependence. It is *asymmetries* in dependence that are most likely to provide sources of influence for actors in their dealings with another. (...) When we say that asymmetric interdependence can be a source of power we are thinking of power as control over resources, or the *potential* to affect outcomes.” (p. 11)

The situation for Poland in relation to the global supply of environmentally sound technologies is one of asymmetry. It is truistic to say that the ‘power as control over resources’ in terms of EST is much greater in the surrounding Western world than in Poland itself. Aid and assistance is the outcome of technological asymmetry among nations and their systems of innovations. This is the equivalent to say that NSIs have different ability to innovate and assimilate.

In terms of technological learning, asymmetries among national systems may be explained by the fact that diffusion of advanced technologies, whether Kondratieffs, systems or singular technologies, will proceed with various NSI assimilation success depending on accumulated capabilities, institutional flexibility or ‘barriers’ (US Office of Technology Assessment 1994).

We would be lucky if the Polish case of EST adoption and assimilation was characterised by catching-up in technology as described by Perez and Soete (1988). Were it the case, that EST could be considered a ‘technological system’ in one of the earlier phases of its life-cycle, then “given a reasonable level of productive capacity and location advantages and a sufficient endowment of qualified human resources in the new technologies, a temporary window of opportunity is open, with low thresholds of entry where it matters most” (p.477). But rather, it seems, and definitely in the cases of end-of-pipe abatement technologies, EST is often the last of the phases (the phase of regrets) of the previous technological generation that had specific environmental effects in relation to its key factors, such as fossil fuel-based transportation and energy systems. This is also one reason why we may expect end-of-pipe EST is suitable for and turned into larger aid transfers.

It can be argued that the Soviet-type entry at Phase I never goes further than that in the Perez-Soete scheme of Phases I-IV in technological life-cycles. As Perez and Soete (1988) write, the last phase of a technological system's life-cycle is characterised by diminishing returns for further investments in technological improvements. This might lead the established firms "to concentrate on other innovations and turn the technology acquired in the previous phases into a commodity, i.e. being willing to sell it at a discretionary price in the form of licenses and 'know-how' contracts" (p. 474). Since CEE is generally unable to pay the prices of EST investments, financing through aid and technical assistance programme is needed.

When the Soviet-type entry occurs, it enters into Phase I *in a second-hand life-cycle*, that is after having introduced Phase IV of the mature technology from the West. Phase I is focused on the product and will in the typical Soviet case never proceed into a focus on rapid market growth (Phase II), managing firm growth and capturing market share (Phase III), though willingness to sell it (Phase IV) again may occur within the protected market (i.e. a second- or third-hand diffusion). Stage I is generally, in market economies, a "learning process for designers, plant engineers, management, workers, distributors and consumers" (p. 472), but will, in the second hand Soviet-type cycle never lead to improved processes (Phase II), scale-up of plants (Phase III) or concentration on other innovations (Phase IV).

Because of the sudden petrifaction of the installation, this is the world of the imitative engineer, rather than the Schumpeterian entrepreneur (phase I of the first wave) or the creative engineer and marketing manager (Phase II). This provides one explanation of the rather vast number of engineers in the Soviet-type NSI, in particular in relation to degree of innovativeness. The actual choice of EST in CEE and Poland would therefore give an indication of the validity of such an explanation of aid assimilation patterns and show to what extent aid projects are generally comprised by mature (Phase IV) technologies turned into commodities, which thus would cement technological lags rather than contributing to environmentally-oriented 'leap-frogging'.

In this context it is therefore relevant to understand the institutional (both Polish and international level) environment for technology selection. It is also crucial to distinguish between aid projects leading to what Freeman (1984) calls "incremental" as opposed to "radical" innovations, since the latter gives more impetus to sector transformations and cyclical diffusion patterns. Given Poland's and general CEE technological standards, it might not be overoptimistic at all, but rather conditional for progress to expect a Polish "technological revolution", i.e. technical change that not only leads to the emergence of a new range of products and services, but also effect every other branch of the economy by changing the input cost structure and conditions of production and distribution throughout the system. The obsolete capital stock in the Eastern bloc, sometimes originating not from the recent, but from two technological generations back ('the third Kondratiev wave', 1880s-1930s, based on steel use), needs to be replaced, whether relying on aid or not.

Agenda 21 places an emphasis on the informed technological choice and its effects on domestic technological capabilities:

> " 34.8. The primary goal of improved access to technology information is to enable informed choices, leading to access to and transfer of such technologies and the strengthening of countries' own technological capabilities."

Poland has realised this, as is obvious from the following official statement of the national environmental policy formulated by the Ministry of Environmental Protection, Natural Resources and Forestry and passed by the Sejm, the Polish parliament, in 1991:

> "The rate of foreign assistance in the overall costs of environmental protection investments in Poland will not be large in financial terms, particularly in comparison to what Poland needs for restoring the environment. It is expected that it will not exceed several tenths of one percent. Therefore, the methods and forms of utilisation of assistance should be an example and model for solutions to be implemented by our own means. The assessment of *the feasibility of multiplication and distribution of acquired technologies*, equipment and instruments, as well as know-how and experience, are to be regarded as the basic criteria for the selection of projects for implementation" (my italics).

There is thus a dilemma for Poland as technology recipient and national system of innovation to the extent that selection of late-stage technological EST systems is shown to be made, since such acquisitions will not promote the domestic capability build-up to the extent defined by the international regime of sustainable environmentally sound development and corresponding national policies. Soviet-type legacies have created a situation were post-communism has to unlearn assimilation patterns in order to reverse the inter-NSI asymmetry, characterised by late and poor introduction of key factor technologies in some NSIs from technologically more powerful NSIs.

Western Environmental Aid

While history definitely has not come to an end, the Cold War has. The velvet revolution in CEE from 1989 and the collapse of the Soviet Union in 1991 has reversed the Western policies toward the East. Help and assistance in transforming old command economy systems into market-economic ones has been a general goal of OECD countries together with programmes to improve environmental protection in CEE. From being indirectly technologically responsible for environmental degradation during socialism, through earlier exports of un-sustainable technological styles to the East, and later highly restrictive to provide the most pioneering technologies for the next generation of technologies, the Western world is now inclined to integrate parts of the East and help it to upgrade its technological basis along with giving assistance to the restructuring of socio-economic institutions.

In this pursuit, there is now a large number of institutions granting aid and technical assistance in various forms to Central and East European Countries (CEE) and the Newly Independent States (NIS) of the former Soviet Union. The World Bank, the European Bank for Reconstruction and Development, as well as regional institutions and national donor agencies have since 1989 worked on programmes to support democratic and sustainable transformation in post-communist Europe.

Total environmental aid to CEE in the 1990-1995 period amounts to 3.4 billion ECU according to recent estimates. The World Bank has provided more than a third of that amount, EBRD a sixth and Germany and the European Union more than a tenth. As the second largest bilateral donor we find Denmark.

Among the recipient CEE countries of that aid, Poland has been by far the most successful; with a total environmental aid value of more than one billion ECU, which is almost two third more than the second in line - the Czech republic. This fact is one major reason for starting the analysis of environmental aid assimilation to post-communist nations with Poland.

Donor institutions, such as the World Bank (IBRD) and the European Bank for Reconstruction and Development (EBRD) has integrated the principles of 'sustainable development', as defined in Agenda 21 at the Rio Earth Summit in 1992, into its policies. Poland has also, as signing party of a 'European Agreement', been subject to integration measures for accession into the European Union. In this respect, aid is also given for purposes of institutional learning, as defined by Dalum *et al.* (1992) with specific environmental implications.

Table 2. Environmental Aid to Central and Eastern Europe by Donors, 1990-1995 (M ECU)

Donor	*Amount*
Word Bank	1243.91
EBRD	667.08
Germany	392.42
European Union	351.17
EIB	196.90
Denmark	92.22
USA	74.83
Austria	59.93
Sweden	51.68
GEF	49.43
Switzerland	41.49
Finland	36.04
NIB	35.30
The Netherlands	32.02
NEFCO	29.02
Norway	27.12
Japan	13.01
France	11.21
UK	10.16
Total	3414.94

Source: Task Force (1995)

Table 3. East European Countries as Recipients of Western Environmental Aid 1991-1994

Recipient CEE Country	*Total Environmental Aid (M ECU)*
Poland	1007.6
Czech Republic	357.7
Bulgaria	289.2
Hungary	236.6
Rumania	190.1
Slovakia	168.1
Russia	164.6
Estonia	135.9

Source: Task Force (1995)

Prevailing Post-Communist Barriers to Learning?

The Problem Then

Poland has an discouraging record of assimilating Western technology. Writes Fallenbuchl about the Polish "the new development strategy" in the 1970s:

> "the Polish experience shows a very serious weakness. The economic results of technology transfer were drastically reduced by delays in the utilization of purchased

technology, in the construction of plants, in the installation of imported machines and equipment and in the achievement of the full scale of production" (p.47).

Similar results had been reported about the USSR (Hanson and Hill 1979). We can thus conclude there did exist a Soviet-type pattern of problematic technology assimilation. One major reason was that institutional accommodations (institutional learning) were never made; "adequate distribution network, the application of modern marketing techniques, servicing and spare parts" (Fallenbuchl, p. 87) were lacking in the Soviet-type system. Similar causes for Soviet assimilation problems were found in my study of study of Soviet assimilation of Swedish plant transfers (Sandberg 1989). As states Lundvall (1992): "Product or process technologies borrowed from abroad do not automatically fit into new institutional set-ups" (p. 311). Accommodation of the receiving institutional system, as well as the innovation itself, becomes necessary. The problem of the Soviet-type system, however, was its rigidity - the reluctance to change was too strong within the regime and the industrial leadership.

The Problem Now

First we thus have the problem of transfer timing in the choice of technologies. Perez and Soete (1988) suggest that this is a question of technological strategy which will bear upon the international technological asymmetries and Poland's position in that international system. This is the technological aspect of assimilation.

The institutional aspect of learning (accommodation) of the Polish NSI refers to the process of facilitating efficient assimilation once technologies have been chosen. However, despite the ongoing transformation process following the 'velvet revolution', there looms a fear based on recent observations that the post-communist pioneer not yet has overcome major Soviet-type institutional barriers to technological learning, traditionally implying poor assimilation of transferred technology. One central distinction between an NSI approach to studies of developing countries or developed countries on the one hand, and post-communist (or communist) countries on the other, is that the latter to a much larger extent will need to institutionally re-learn or un-learn than the former. Re-learning/un-learning might also be more difficult than 'ordinary' learning. As Dalum *et al.* observe, "there is usually more resistance to institutional change than to technical change" (p. 313). In the case of command economies, the resistance may be even larger because institutions not only need to be changed, but discarded ('forgotten' or un-learned) altogether. "One might argue", write Dalum *et al.* (Lundvall 1992),

> "that several of the most serious unsolved problems of the world (as remembering and forgetting) reflect institutional barriers to change rather than a lack of technical knowledge. (...) Even more obvious, the breakdown of the old economic institutions in Eastern Europe and the Soviet Union has been connected to, quite simplistic, ideas of institutional borrowing through an importation of the institutions of private ownership and the free market from the West. (...) The possibility of international borrowing, as an integral element of institutional learning, becomes still more interesting when questions of how different institutional traits affect the use of new technology and technical learning come into focus." (p. 310 and 312).

In a recent dissertation (Martinot 1995), the study of transfers of renewable energy technologies to Russia shows that assimilation is hampered by exactly such, still-prevailing, post-Communist institutional barriers:

> "The evidence illustrates that many transaction barriers severely limit economic activities, including technology transfer, that would result in greater energy efficiency and renewable energy supplies. Lack of developed capital markets and long-term capital is a commonly cited problem for Russia. But even with greater capital availability, uncertainty and lack of

> information in different forms represent formidable transaction barriers. Other barriers relate to missing institutional mechanisms; missing or mismatched incentives; weak legal and market institutions; cultural factors; and a lack of experience and training in economic management, finance, law and marketing" (pp. 1-2 in Martinot 1995).

From World Bank aid evaluations it is also clear that Poland still has a limited technical capability of implementing projects (World Bank 1995). US Congress sources suggest institutional, as well as economic and technical barriers to energy-related transfers of EST to CEE (US Office of Technology Assessment 1994).

Considering the Polish national system of innovation in relation to inflow of environmental aid and EST, and considering the low level of Polish domestic EST capabilities, the assimilation perspective, i.e. learning on the basis of foreign technology, must focus on the extent to which Poland is overcoming barriers to efficient EST learning. Indigenous learning is not irrelevant given that perspective. On the contrary, in order to trace indigenous EST learning we need to look at end-use of environmental aid, in order to detect cases of indigenous build-up of EST capabilities on the basis of received aid.

A Note on Technology Assimilation Analysis of Aid versus Aid Evaluation Analysis

The major distinction between an aid assimilation analysis and an aid evaluation analysis is the relationship between independent and dependent variables. In the aid assimilation analysis the focus is directed toward the interaction between the major dependent variables (aspects of assimilation and incorporation) and independent variables, i.e. those of the environment of assimilation, such as the recipient firm or country, but also international conditions. We thus explain "whether the receiving country's social, political and economic environment can accommodate and make full use of the potential of the project" (Carlsson *et al.* 1994). Cost-benefit analysis or aid evaluations in general, on the other hand, focus on the effects of the project on the recipient society. The major causal direction of assimilation and cost-benefit analyses are thus opposites.

Conclusion

It is suggested in this paper, that specific circumstances provide substantial - and historic - opportunities for Poland as a pioneer of a 'greener post-communism': the paradoxical effects of the membership in the Soviet bloc which present the Polish reformers with important opportunities for environmentally sound modernisation and nature conservation; the technological revolution on a global scale concurrent with the Velvet Revolution; new environmentally sound technologies which are increasingly available for transfers in the form of environmental aid.

Approaches to 'technological revolutions', life-cycle timing in 'entry' and introduction of innovations, to 'technology assimilation' into the Polish 'system of innovation' and the experiences from technology transfers to Poland and the former Eastern bloc, including Russia, suggest that the success in capitalising on these opportunities to environmentally sound modernisation will depend on the ability to overcome prevailing barriers to learning and technology assimilation.

Though the thrust of the paper is to suggest an assimilation analysis for assessment of Polish environmentally sound technological learning, in doing so, an integration attempt of the 'technology assimilation' and 'international regime' concepts into the approaches of 'national systems of innovation', 'longer waves' and technological entry into life-cycle 'phases' is the major task. National systems of innovation are suggested to capitalise on global diffusion of technological waves, systems and singular technologies depending on adaptation (such as integration into the European Union) and accommodation of institutional set-ups (overcoming barriers) in order to improve assimilation (e.g. through technological life-cycle entry policies). At the inter-national systems level, international regimes create specific constraints to the entry or choice through norms, rules and governance. Because national systems are unequally successful in such assimilation, there is an asymmetry at inter-national systems of innovation level.

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