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Nations

The celebration of the inventive citizen has been an important part of modern nationalism. This invention-chauvinism is, like nationalism, a global phenomenon. Curators of national traditions overestimated the significance of inventors that shared their particular nationality, overemphasised national connections, and made too much of the significance of making things first. 'No we do not have pasteurized milk in France, but we do have Pasteur', said a Frenchman to an American in the 1960s.[1] Juan de la Cierva (1895–1936) is regarded as one of the greatest Spanish inventors, but although he invented and developed the *autogiro* (a flying machine with rotating wings, a little like a helicopter) in Spain, he set up an enterprise in Britain. Or consider Ladislao José Biro (1899–1985), 'without doubt the most important Argentine inventor there has been'.[2] But the context for his invention of the ballpoint pen, or biro, was the increasingly anti-semitic Hungary from which László Jozsef Bíró emigrated in 1938. Famously, in its most nationalist phase, the Soviet Union was able to find Russian inventors for many important technologies, thus Alexander Stepanovitch Popov (1859–1906) invented radio.

In Britain, France and the United States people laughed too easily at what they saw as techno-nationalist excesses in other countries. For here too very similar excessively nationalistic emphases were at work – it would have been hard for a British person to know that radar, the jet engine or even television were not uniquely British inventions. The great technological and scientific museums of the rich world, such as the Science Museum in London, the Deutsches Museum in Munich and the Smithsonian Institution in Washington, are not replicas of each other, or complements, but in some senses competitors too. As a result of this emphasis on national inventiveness, the relations of nations and technology are particularly prone to being discussed in terms of invention and innovation.

Techno-nationalism takes other forms too, for example in claims that this or that country is best fitted for the technological age. The creation of new national identities suited for a technological age was happening around the world. There was hardly a nation that did not have intellectuals who thought his or her nation was best fitted for the 'air age'. Interwar French writers argued that as a vital and aesthetic people the French were particularly suited to be aviators.[3] Hitler thought war in the air was a particularly Germanic form of battle.[4] Sir Walter Raleigh, Professor of English at Oxford and official historian of the Great War in the air, claimed in the 1920s that Britain 'had a body of youth fitted by temperament for the work of the air, and educated, as if by design, to take risks with a light heart – the boys of the Public Schools of England'.[5] Soviet record-breaking pilots, dubbed 'Stalin's falcons', were closely associated with the 'New Man' and with Stalin himself.[6] The Russian-born aircraft manufacturer and propagandist Alexander de Seversky claimed that 'Americans are the natural masters of the aerial weapon … more than any other people Americans are the natural children of the machine age'; 'Air power is the American weapon.'[7] Yet the inverse problem is just as significant: the attribution to *another* nation of extraordinary technological powers which elude one's own. For example, the feeling in Britain that Germany, then the United States and the Soviet Union, and latterly Japan, does technology better, and that there is always one country which does it best. Thus Lindberg's transatlantic flight of 1927 was hailed in Europe as well as America as evidence of the vigour of the New World.[8] Communists everywhere saw in 'Stalin's falcons' evidence of the superiority of Soviet society.[9] Fascists, and indeed some anti-fascists, saw Nazi

Germany and Italy as the nations best fitted to aviation. More recently Japan was widely regarded as the nation most suited to the electronic age. Individually such claims might seem credible, and have mislead many into thinking too nationalistically about technology, but collectively they contradict each other.

Techno-nationalism assumes that the key unit of analysis for the study of technology is the nation: nations are the units that invent, that have R&D budgets, cultures of innovation, that diffuse, that use technology. The success of nations, it is believed by techno-nationalists, is dependent on how well they do this. This techno-nationalism is implicit, not only in any number of national histories of technology, but also in many policy studies, for example of 'national systems of innovation'. Particular technologies are associated with particular nations. Cotton textiles and steam power are seen as British, chemicals as German, mass production as American, consumer electronics as Japanese.[10] This is despite the fact that all these countries were strong in all these technologies.

On the other hand, we have techno-globalism, particularly focused on communications technologies, which endlessly repeats the idea that the world is becoming a 'global village'. In this old-fashioned view nations are always about to disappear through the advance of globalising new technology. The steam ship, the aeroplane, the radio, and more recently television and the internet, it is argued, are forging a new global world economy and culture, and the nation is at best a temporary vehicle through which the forces of techno-globalism operate.

Nations are important in ways techno-nationalism cannot capture, and the international and global dimension is crucial in ways which techno-globalism is ignorant of. In any case, politics, multinational firms, empire and race were also crucial factors in shaping the use of technology which cut across the national and global divide in complex and changing ways. The nation and the state are central to the history of twentieth-century technology, but not in the ways the relations are usually understood.

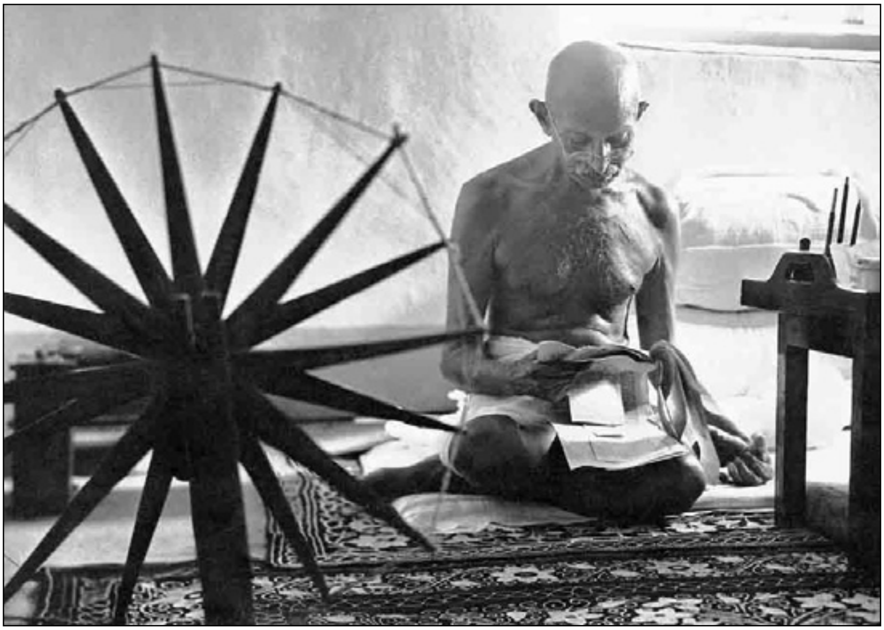
Techno-nationalism

Nationalism, that great hidden ideology of the twentieth century, has been thought of as a deviant notion compared to more acceptable, and seemingly less ideological, liberal and internationalist ideas. Nationalism is seen as an ideological throwback – like militarism and linked to it – a stirring up of supposedly ancient bonds of blood. It is a dangerous blast from the past. Not surprisingly, the linking of nationalism and technology has not been looked on favourably. Thus the term techno-nationalism is used by Western analysts primarily in relation to Japan and now China, to describe a potentially, perhaps actually, dangerous thing.

To suggest that techno-nationalism applies only to such countries would be a great mistake. Intellectuals were very nationalistic about science and technology, particularly in mid twentieth century, in nearly every nation. Indeed nationalism is not only present but very similar in many different nations. Every country had it, at much the same time and in much the same way, even though its central claim was for the uniqueness of each nation. One reason for this is suggested by Ernest Gellner's account of nationalism. For Gellner, nationalism was a way of adapting to a modern, industrial and globalising world. It was a global response to a global phenomenon. The idea is this: in a modern industrial society, where education, bureaucracy, information and communication mattered deeply, to be alienated from all this by linguistic and cultural barriers was intolerable. Hence these functions needed to be carried out in the language spoken by the people. Nationalism, which was something new, was thus vital to modernity. Nationalism in this sense is not a way of escaping from a globalised cosmopolitan modern world, but a means of participating in it while retaining one's dignity, and indeed creating one's capacity to participate.[11]

National innovation and national growth

An implicit techno-nationalism is found in an extreme and widespread form in the assumption that *national* economic and technological



15. A national technology. Mahatma Gandhi reading newspaper clippings next to a Charkha (spinning wheel), the great symbol of the Indian National Congress. The spinning wheel was re-introduced into India in the twentieth century as a result of a campaign led by Gandhi to promote 'production by the masses'.

performance is determined by *national* rates of invention and innovation. It is there in the standard market failure argument, developed in the United States in the late 1950s, for state support of research. The argument was this: individuals in a society would not fund enough research because others could make use of the research just as much as the funder could. This is the famous 'free-rider' problem. The market failed, and thus government should step in to fund research, which would benefit everyone. Of course, states, including the US, supported research long before this argument was put forward, and of course would continue to do so for other reasons. Yet the argument worked only for a closed system, if each nation was insulated from every other one. For the free-rider problem would otherwise also apply to governments – why should the Indian government fund research that would equally be exploited by Pakistani, or US citizens? We should recognise of course that in the 1950s the US dominated world research and development, and thus could be thought of as a closed system.

This implicit techno-nationalism is also found in another justification for national funding of research (and development). It is the idea that to overtake rich countries a nation needs to invent and innovate more, and that if it does not it will descend to the level of the poorest countries. Even casting doubt on the role of *national* R&D can lead the analyst to be accused of being indifferent to their nation becoming like Bulgaria or Paraguay. In such arguments it is often first claimed that invention and innovation is of huge importance to other nations, and then that Britain, India or, say, Thailand spends much less on R&D than the United States and Japan. Thus Spaniards complain that Spain's share of invention has been lower than its share of population, and indeed production. But Spaniards compare themselves to the richest countries in the world, not the world as a whole.[12]

This innovation-centric techno-nationalist understanding is central to national histories of technologies. Historians and others have assumed that Germany and America grew fast in the early years of the twentieth century because of rapid national innovation. They also argued that the British 'decline' (that is slow growth) must have been associated with low innovation, indeed this 'decline' was itself taken as evidence of poor innovation. For example, a recent book on innovation and economic performance, most of it arranged in typical fashion in chapters based on *nations*, expresses surprise that in the case of Japan recent economic performance has not been on a par with the country's huge R&D spending, which is second only to that of the USA in scale.[13] In the 1990s crude versions of endogenous growth theory, which claimed that inputs such as R&D led to growth, globally and nationally, flourished.

So powerful has this innovation-centric view been, especially in its nationalistic versions, that all evidence to the contrary has been studiously ignored. It was known in the 1960s that national rates of economic growth did not correlate positively with *national* investments in invention, research and development, or innovation. It has *not* been the case that countries that innovate a lot, grow a lot. Take, for example, Italy and the United Kingdom. Each was very different in 1900 but not so different in 2000. In the 1980s Italy overtook the United Kingdom in output per head, a shock the Italians named *il sorpasso.* That these countries, such opposites in the usual estimations of national character, had now reached the same level of income per head was unsettling on both sides. In the techno-nationalist world it was literally incredible that Italy had become richer than Great Britain, while spending much *less* on R&D than Britain did. Italian scientists and engineers and research policy experts had long complained that Italy was by no measure a great centre of innovation; it has very few Nobel prizes (one is for the polymerisation of the plastic polypropylene), and its expenditure on R&D has been low by the standards of rich countries. In Britain, so peculiar are the politics of technology that it has been claimed that Italy was spending more on R&D than Britain in order to square this particular circle. What one does not find is the acceptance that Italy has been brilliantly successful in that with little R&D, it has become as rich as Britain.

It is important to stress that this is not a unique case. Spain was one of the most successful European economies in terms of rates of growth in the 1980s and 1990s, and yet this is a country which spends less than 1 per cent of GDP on R&D. It had much less of a historical track record in industry and technology than Italy: it is a '*sistema tecnológico que progresa sin innovar*'. [14] The most spectacularly fast-growing economies in world history have been those of some Asian countries, such as Malaysia, Taiwan, Korea, and most recently and significantly of all, given its size, China. While China has transformed itself and flooded the world with manufactures, the much more innovative Japanese economy has been, by comparison, stagnant. Moreover, while national R&D expenditures have increased in the rich countries in recent decades, economic growth rates have dropped below those found in the long boom.

To add further to these seeming paradoxes, the two countries which both grew very fast and had high and increasing R&D expenditure in the twentieth century, the Soviet Union and Japan, were not especially innovative. The Soviet case is particularly stunning. It spent 2.9 per cent of GNP on R&D in the late 1960s, the same as the USA, and spent more than America in the early 1970s. The number of Soviet scientists and engineers in R&D, in absolute numbers, overtook the US total in the very late 1960s, giving the USSR the largest R&D workforce in the world.[15] Yet it is regarded, perhaps unfairly, as having contributed practically nothing novel to modern industry. Japan did better than the Soviet Union after the Second World War, but its record of innovation is felt, again perhaps unfairly, not to be congruent with huge R&D expenditures.

How can we make sense of this? What general rules are there? Firstly, there is a broad rule that richer countries spend a higher proportion of their output on R&D than poor ones. There are exceptions to this: for example, Italy in recent decades was rich but spent little; the USSR, while very poor, spent as much or more than the richest countries. Secondly, the relationship does not necessarily hold over time: as rich countries got slowly richer in the 1980s and 1990s, the proportion of national income spent on R&D remained broadly static, and in some cases fell. There is a second general rule of thumb, again with important exceptions, that the fastest-growing countries are not the richest. The slowest-growing were already rich. The fastest-growing countries in the twentieth century have been poor countries, which spent very little on innovation. Thus taking these two general rules together we can conclude that rich, slow-growing countries spend a lot more on R&D than fast-growing poor ones.

Why does the techno-nationalist assumption about innovation and growth not hold? The link between innovation and use, and thus economic performance, is far from straightforward. Yet the techno-nationalist assumption implies that the things a nation uses derive from its own invention and innovation, or at the very least that innovating nations have early leads in the technologies they innovate. Yet the site of innovation is not always the major site of even early use of the technology. In the case of the motor car, Germany, where the internal-combustion-powered motor car was invented, was not the main early producer of cars in the first twenty years of the industry. The USA became easily the dominant producer by 1914, and Germany remained less motorised than other rich countries for many decades. The powered aeroplane was innovated in the USA by the Wright brothers in 1903 but Britain, France and Germany had much larger air fleets by 1914. As we shall see, photography and television are other examples.

More significantly, national use of technology is hardly dependent on national innovation. Most technologies are shared across national boundaries; nations acquire more new technology from abroad than they innovate themselves. Italy did not have to invent afresh the technology it used, just as Britain did not either. Both were sharing in a global pool, as was every country in the world. One can make this clearer by looking around one's immediate surroundings and asking about the origins of the things one can see; nowhere in the world would more than a small minority be local. Thus it is unfair to complain that of seventy-five major technologies in use in the Soviet Union through much of its history, five were of Soviet origin and ten of joint Soviet origin.[16] One needs to specify the comparator, and to recognise that for most countries, even the richest and most innovative, the proportions may well have been similar.

The concept of technological sharing is an important one. Yet its importance in the history of the twentieth century is obscured by thinking about the movement of technologies across national boundaries in terms of technology *transfer* from technological leaders to others. The term was first used to describe the export of modern technologies to poor countries. Transfer in this sense is much less significant than the movement of technologies between rich countries. The two-way movements between British and France in the twentieth century have been much more significant than those between Britain and India. This is not to deny the importance of movements across technological boundaries. Indeed one of the most important features of the twentieth-century world economy has been the convergence of certain countries on one technological level. The rich countries of the world are much closer in all economic measures than they were in 1900. These countries have borrowed from each other and perhaps most from a particular technological leader which set the highest level. Italy, Spain, Japan, the USSR and now China have been imitating foreign technologies on a huge scale, and this has been an essential aspect of their rapid economic growth.

There is one very special case in this story of convergence among the richest nations. In the nineteenth century the USA did not catch up with Europe in terms of productivity, it shot ahead. Through the twentieth century it remained ahead, with, in the middle of the century, productivity levels at least twice as great as that of the European industrial giants. This lead did not come from dominance in 'pure science' or even 'industrial research' – in 1900 America was the leader in neither. Where historians have claimed to find US distinctiveness and a particular surge in innovation is in production technology – the sort of thing which led to mass production. Yet, the evidence for the centrality of US invention in this area is not as strong as nationalistic analyses of American technology would have us believe. There were extraordinary flows of technological know-how across the Atlantic in the late nineteenth and early twentieth centuries.[17] By mid-century however, the USA was a clear leader in industrial research and innovation by any standard: it dominated both world production and world innovation. As such it was wholly atypical, and exactly the sort of case where we would expect technologies to derive from national innovation. Only perhaps in the exceptional case of the United States after the Second World War might locally innovated products have registered strongly. Many studies show that US innovation promoted US growth – the mistake was to believe that this applied to other countries too, and that the rate of growth in America was particularly high.

We may conclude, then, that global innovation may be the main determinant of global economic growth, but it does not follow that this is the case for particular nation states. Since national innovation has not been the main source of national technique, it should not be at all surprising that there is no clear positive relationship between national innovation and national rates of growth. Global technological sharing, between rich countries and between rich and poor, has been the norm. Should we, then, discard techno-nationalism, and think techno-globally?

Techno-globalism

While techno-nationalism has been a core assumption in much thinking about the nation-state and technology in the twentieth century, there has also been a techno-globalism which claimed the globe as the key unit of analysis. It often looked forward to technology eliminating the nation-state, which it regarded as an outmoded organisation. Most techno-globalism has been innovation-centric, and it is this kind of techno-globalism which has been at the heart of any number of histories of the world, the musings of information society gurus, and many a portentous address about science and technology. It has been claimed that the world has been going through a process of globalisation as a result of the latest technologies, for well over a century.

In the late nineteenth century the steam-ship, the railway and the telegraph reached across and into the world which was, with justification, seen as interconnected as never before. Yet that globalisation was ignored when claims for new technologies of globalisation were being made just a little later. Thus in the 1920s Henry Ford in *My Philosophy of Industry* claimed that

> Machinery is accomplishing in the world what man has failed to do by preaching, propaganda, or the written word. The aeroplane and wireless know no boundary. They pass over the dotted lines on the map without heed or hindrance. They are binding the world together

> in a way no other system can. The motion picture with its universal language, the aeroplane with its speed, and the wireless with its coming international programme – these will soon bring the world to a complete understanding. Thus may we vision a United States of the World. Ultimately it will surely come![18]

For Henry Ford, 'The motor-car has done for the United States what the aeroplane and wireless may do for the world.'[19] Twenty years later the Canadian Air Marshal and Great War air ace Billy Bishop claimed that 'The horse and buggy developed purely local geographical cultures. Railway trains and motor cars developed nationalism.' This begs the question, of course, when the age of the train and the motor car was, but in this innovation-centric account, it was passing. With the aeroplane came the necessity, as Bishop saw it, for 'the establishment of *world* culture, a *world* view of the responsibilities of citizenship … The Air Age must bring us entirely new concepts of citizenship, of national and international relations.' The choice was between 'Winged Peace or Winged Death'.[20]

H. G. Wells was one of the great propagandists for this kind of thinking. In the *Shape of Things to Come: The Ultimate Revolution* (1933) airmen bring peace and civilisation to a war-devastated world.[21] Wells imagined a Conference in 1965 of scientific and technical workers in Basra, Iraq. It was organised by the Transport Union, which brought together surviving aeroplane and sea transport, and used as its language the Basic English of the aviators.[22] As a result there was central control of the airways, with an air force to enforce peace. The unit of currency was the air dollar.[23] The Air and Sea Control and the Police of the Air and Seaways were owned by the Modern State Society, made up of qualified fellows. In 1978 they decided to put down the re-emerging national governments' opposition with a new gas called Pacificin. Wells was not alone in putting forward these ideas. In the early 1930s there were all sorts of suggestions for the creation of an 'international air police' along these lines, and similar thinking continued into the 1940s, usually with the British and Americans as that international police force. In more recent years the atomic bomb, television and above all the internet and the world-wide web have featured in this kind of techno-globalism. As we have seen, it was generally the older technologies which were crucial to global relations – today's globalisation is in part the result of extremely cheap sea and air transport, and radio and wire-based communication.

Historically aware and more knowledgeable commentators could not stomach this kind of stuff. In 1944 George Orwell noted the repetitiveness in the claims:

> Reading recently a batch of rather shallowly optimistic 'progressive' books, I was struck by the automatic way people go on repeating certain phrases which were fashionable before 1914. Two great favourites are the 'abolition of distance' and the 'disappearance of frontiers'. I do not know how often I have met with statements that 'the aeroplane and the radio have abolished distance' and 'all parts of the world are now interdependent'.

But Orwell criticised not only the historical amnesia involved. He claimed there was a quite different relationship between technology and world history. 'Actually,' he claimed, 'the effect of modern inventions has been to increase nationalism, to make travel enormously more difficult, to cut down the means of communication between one country and another, and to make various parts of the world *less*, not more dependent on one another for food and manufactured goods.'[24] He was thinking about what had been happening since 1918, and particularly since the early 1930s. His was a powerful and defensible argument.

The great era of global trade had ended in 1914. In the interwar years trade stagnated and fell, and especially in the 1930s nation-states all over the world became increasingly autarkic. In the middle of the twentieth century the world was much less globalised than it had previously been, and would be at the end of the century. There was a profound nationalisation. There was also a powerful move to turn political empires into trading blocs to a degree unknown before. Innovation-centred political history puts the great age of nationalism in the nineteenth and early twentieth centuries; the age of imperialism is placed between the 1870s and the First World War. Yet empire accounted for a greater proportion of trade in the 1930s, 1940s and 1950s than it did in the pioneering days of the new imperialism. Nationalism was at least as important in the middle of the twentieth century as it had been earlier. And, as Orwell noted, science and technology were key tools of autarky, the policy of national economic self-sufficiency in the 1930s and 1940s. He pointed in particular to the role of the aeroplane and the radio in bolstering this new and dangerous nationalism. In other words, the very technologies that were at the heart of the naïve techno-globalism vision of an interconnected world were the tools of a new national despotism.

One can go much further than Orwell did in ironically inverting the claims of innovation-centric techno-globalist propaganda. For many of the technologies invoked as being somehow essentially internationalising were profoundly national in origin and use. Radio, which had a military origin, was intimately connected to national power. The development of the radio before the Great War was intimately tied to navies – indeed the Royal Navy was the largest single customer for the Marconi Company, which led the world in radio. During and after the Great War, radio and the military remained closely connected; the Radio Corporation of America, for example, was closely tied to the US state.[25]

More stunningly still, the aeroplane was primarily a weapon of war, even in peacetime. Far from threatening to transcend the nation, it was the product of a system of competing nation-states and empires. In peace as in war, the aircraft industry was utterly dependent on the patronage of the military. In peacetime some three-quarters of the output of all the main aircraft industries in the world went to the military. In the interwar years air forces had hundreds of aircraft, airlines tens. Since then, too, the military continue to dominate aircraft industry sales. Yet, to this day histories of technology treat aviation under transportation; histories of aviation are really histories of civil aviation, and technical development is seen as driven by civil transportation needs. Histories of the aircraft-producing industry also overemphasise the significance of the production of civil aircraft; accounts of the industry in peacetime are accounts of the production of civil aircraft.[26]

But radio and the aeroplane were not the only cases. The atomic bomb was also the product of a world of competing states. So too was the internet, born of US military needs and funding. Many other great technologies of the twentieth century were technologies of autarky and militarism. Oil-from-coal, many synthetic fibres and synthetic rubber are just a sample of the technologies which would not have survived in a global liberal free market. They were the product of the particular state system which operated to force nations into certain relations with each other. The very specific role of the state, and the specific nature of its competition with other states, has given *states* particular roles in the promotion of *particular* technologies. Even techno-nationalists have not recognised the centrality of the state system to twentieth-century technology. Techno-national projects were of the greatest importance, though their histories are not to be found in techno-nationalist writings.

Autarky and things

Political and technological boundaries are different, but states have often acted to bring them into line, by controlling the movement of things across borders and by developing particular national technologies. They have controlled the movement of things by tariffs, quotas and nationalistic procurement policies. They have developed national technologies by insulating the nation from the rest of the world, and by the direct funding of national innovation programmes. This practical technological nationalism has had wonderfully contradictory effects – far from making national technologies different, it has encouraged movement of technologies across political boundaries. It has also helped impoverish nations rather than strengthen them.

In the histories of some nations, autarky became an explicit political economic programme, with the term itself being used by political actors, and historians have had no trouble in using it too. The most obvious and important cases are Italy under fascism, Nazi Germany, and Francoist Spain, where the period of *autarquía* lasted to 1959. Government protected industry, they engaged in import substitution, they promoted strategic industries, linked to the military, and the state often had great control over domestic industry, sometimes through specialist bodies such as Mussolini's IRI (Industrial Reconstruction Institute), and its Spanish variant established in 1941, the Instituto Nacional de Industria.[27] The Soviet and Chinese blocs were also autarkic. Indeed, autarky was to become most extreme in nations which were isolated from the capitalist world and the socialist blocs. In North Korea *Juche* (self-reliance) was pursued from the 1960s when the country was isolated from both China and the USSR. Albania relied on the Soviet Union until 1960 and on China thereafter, but became increasingly autarkic from the early 1970s, and especially from 1978 when China removed all support.

In the middle years of the century many more countries were autarkic. Throughout the world, countries sought to industrialise, to replace imports with domestic goods, produced by local companies. Among the countries that turned to autarky was that previously enthusiastic champion of free trade, Britain. Greece, the great commercial centre of the eastern Mediterranean, hardly known for manufacturing, also turned to autarky, under Metaxas in the 1930s. Often war elsewhere was crucial, forcing autarkic development to replace imports that were no longer available. Virtue was made of these necessities, for example in Argentina under General Perón, where national industrial development became a central policy of the regime. Similarly, India, South Africa and Australia developed new industries in this period.

Autarky was supported by elements of the left, as well as the right. In the 1960s Latin American dependency theorists complained that under free trade nations exported raw materials while even their most basic manufactures were imported; they attacked their own countries as places which made nothing, invented nothing, which were for ever subservient to the metropolis. Breaking away from the world market, and developing national industries was essential to development and to independence. The European left too, at least in part, wanted to promote national industrial development strategies, and thus rejected free trade and indeed the European Common Market.

Hydrogenation

At the beginning of the twentieth century a French chemist, Henri Sabatier, showed that metal catalysts could be used to make possible the hydrogenation (the chemical addition of hydrogen) of many compounds, organic and inorganic. Three uses of hydrogenation turned out to be particularly important: the manufacture of margarine, ammonia and petrol. All three processes produced substitutes for older products: ammonia was used to make nitrates, replacing nitrate from Chilean guano deposits; petrol made from coal replaced that distilled from petroleum; margarine made from hydrogenated fats and oils substituted for butter and other forms of margarine. All three were to be closely connected to the national question in the twentieth century.

The hydrogenation of nitrogen to make ammonia, pioneered by the German chemical firm BASF before and during the Great War, was of enormous importance to national power, not only because it created locally produced nitrogen fertiliser, but also because nitrate was a major source of explosives. In 1913 BASF began production at Oppau of synthetic ammonia, and a new plant was built at Leuna in 1917. Coke, steam and air were the raw materials. In the war Oppau developed and operated the process for making nitrate from ammonia. No great power, it seemed, could be without 'synthetic ammonia', and governments sought to develop the Haber-Bosch and other processes (for there were a number of alternative ways of making synthetic fertilisers). In Britain, for example, synthetic ammonia, became central to the new enterprise, Imperial Chemical Industries, founded in 1926, taking over an initially state-sponsored project to make synthetic ammonia and nitrates at Billingham. Yet synthetic nitrogen fertiliser (mostly, but not only Haber-Bosch) was to become extraordinarily global, and indeed an industry of profound importance, particularly after the Second World War. Nitrate was poured on to the world's fields after 1945, so much so that, by the end of the century, some one-third of the nitrogen in human food came from human-made nitrate.

Perhaps the most important use of hydrogenation in terms of its national associations was the hydrogenation of coal. In the rich countries of the world, coal was the dominant source of energy of the first half of the twentieth century. Yet, very quickly petroleum became important as a source of power for cars, trucks and aeroplanes (petrol) and ships (diesel and fuel oil). The leading western European nations did not have their own sources of supply – the main producers were the USA, Russia, Romania and Mexico. The German chemist Friedrich Bergius developed processes for making cheap hydrogen from coal; he then hydrogenated heavy oils, and in 1913, coal. Bergius started building a plant in Rheinau in 1915, to produce his oil-from-coal. This massive project was embarked on because Germany was about to become fatally short of petrol for the war effort. But Germany and Austria defeated Romania in 1916, and were thus able to secure access to its huge petroleum production. The lengthy and hugely expensive Rheinau enterprise was not completed before 1924. It was financed by various private firms, including Royal Dutch Shell and then BASF. IG Farben (a merger of the main German chemical firms including BASF) developed a variant of Bergius, with different catalysts and started building a plant at Leuna in 1927 (where it had hydrogen capacity for synthetic ammonia production). This ambitious new project brought together the main German chemical companies in the 1920s. By 1931 300,000 tons of petroleum were being produced (or in oil terminology, 2.5 million barrels) per annum.

For the Nazis, self-sufficiency in fuel was a top priority under the four-year plan of 1936, and the establishment of synthetic-oil production was a key element towards the achievement of that objective.

Hermann Goering was appointed 'fuel commissar'. The process chosen was IG's hydrogenation, and the company built and ran many plants, including one for the new coal-based chemical complex at Auschwitz. As ever there were alternatives, and indeed the Fischer-Tropsch process, involving the hydrogenation of carbon monoxide rather than coal was also used. Other alternatives included generators of gas from wood for powering cars.[28] By 1944 production was up to 3 million tons, or 25.5 million barrels annually. These synthetic oil plants were extremely important to the German fuel economy during the war, and particularly so in the production of aviation fuel.

After it was defeated, Germany was banned from hydrogenating and in 1949 was ordered to dismantle its plants. The Soviet Union took four to Siberia. Later in 1949 the decision was changed and the plants were converted to cracking petroleum. In East Germany, isolated from western oil markets, coal was hydrogenated until the 1960s.[29] The chemical industry remained coal-based until increased shipments of petroleum from the USSR arrived in the 1950s. With the restriction of Soviet oil exports after 1979, there was a shift back to coal during the 1980s, another case of reappearance, with dire ecological consequences as the German brown coal generated a good deal of acid rain.[30]

Coal hydrogenation was taken to many countries, but it never went global. In an autarkic age, technologies of autarchy internationalised. By the early 1920s the key patents were controlled by IG Farben in Germany, but the international rights in the early 1930s were controlled jointly by IG Farben, Standard Oil of the USA, the Anglo-Dutch oil company Royal Dutch Shell and the British chemical combine ICI. In Britain and the United States plants were built. In Britain ICI, taking over a good deal of work done in a government research station, set up a plant in Billingham which produced petrol between 1935 and 1958. As in Germany, the petrol produced had to be subsidised by various means. Spain developed a synthetic-fuel programme at Puertollano (Ciudad Real) following a 1944 deal between the pro-Axis Spanish government and Germany. In 1950 new deals were signed with BASF and others for technology and plant was built.[31] Production started in 1956 and lasted until 1966. Spain had a hugely expensive R&D programme in the late 1940s and early 1950s, reaching 0.5 per cent of GDP, a remarkable proportion for a poor country of the period.[32]

Another case was coal-rich South Africa where in 1955 the Sasol company started producing petrol using the Fischer-Tropsch process. Following the Arab oil embargo of 1973, Sasol II was built; the cutting off of supplies from Iran after that country's 1979 revolution led to Sasol III.[33] Like the German plants, the Sasol complex was bombed, not by the United Nations, but in June 1980 by Umkhonto we Sizwe (Spear of the Nation), the armed wing of the African National Congress. The attack marked a very important point in the development of the guerrilla war against the apartheid regime. Racist South Africa, run by its National Party, produced 150,000 barrels per day, twice the level of synthetic fuel production in Nazi Germany.[34] Oil-from-coal research started up again on a large scale in the 1970s, as the price of oil increased in 1973 and 1979, and looked to stay high. The oil companies and governments were involved once again, and sought out the records of the earlier Nazi effort.

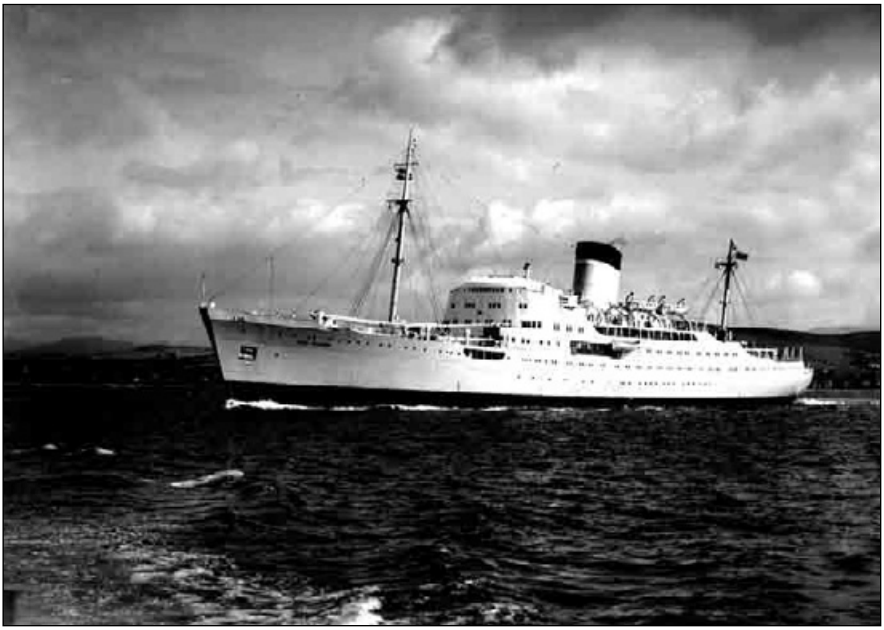
In the history of research and development coal hydrogenation should have a very important place. It was the biggest single project of the world's greatest chemical firm of the 1920s and 1930s, IG Farben, and of Britain's ICI in the late 1920s and early 1930s, as well as post-war Spain, and South Africa. Yet it never produced petrol which could compete in world markets. As a source of petrol it was of minor importance, except in the special cases of Nazi Germany and South Africa. In both places it was significant to history. It kept the Luftwaffe flying and apartheid in business.

The nation is not everything

Technology, like nationalism, crosses national borders; it does so in times and contexts we might not expect from national histories. For example, in nationalistic, totalitarian, autarkic, fascist Italy of 1935, there were places better connected technologically to the United States than to the rest of Italy. A case in point was the village of Aliano in what is now called Basilicata; there were 1,200 inhabitants, one car, one toilet, and far too many malaria-carrying mosquitoes.[35] Yet the mechanical equipment of the village was American; its weights and measures the pounds and inches of the Anglo-Saxons, rather than the kilogrammes and centimetres of continental Europe. The women wove on ancient looms, but used scissors from Pittsburgh; the axe blades of the peasants came from America.[36] How come? Some 2,000 men from Aliano lived in the US and sent home a 'stream of scissors, knives, razors, farm tools, scythes, hammers, pincers … all the gadgets of everyday life'. The carpenters of Grassano, a larger and richer town, had American machinery.[37] Connections between peoples did not follow the boundaries of nation-states, and had a consequence for the traffic in things.

More remarkable is the case of military technology after the Second World War. Despite the Cold War and intense national efforts to develop national technology, in the 1950s the USA, Britain and the Soviet Union shared a remarkable amount of technology, aside from captured German technology. The multinational atomic bomb project became more multinational still, not because of scientific or technological internationalism, but because of espionage by *political* internationalists. They helped ensure that the Soviet Union made a near copy of the plutonium bomb in 1949.[38] Britain's bomb, tested in 1952, also replicated the Los Alamos plutonium bomb. The first atomic bomber of these three powers was the same one too: in the early 1950s, all three were using the Boeing B-29. Britain was loaned them by the USA between 1950 and 1954. The USSR had a fleet of Tu 4s, copies of B-29s forced down on Soviet territory during the war. In addition British Nene and Derwent jet engines (and also copies) powered Soviet jet aircraft, notably the MiG15s over the skies of Korea (the transfer was authorised in 1946).[39] Indeed, the Nene engine was everywhere.

After the Second World War a remarkable range of countries decided they needed not only to acquire jet fighters, and to manufacture them, but to design them. Many of the experts came from



16. One of three passenger, cargo and refrigerated-meat liners built in Britain for a newly nationalised Argentine merchant line in the late 1940s. They were named Eva Perón *(shown here in trials on the Clyde, and the ship on which the author travelled to Britain in 1970),* President Perón *and* 17 de Octubre. *After the fall of Perón they were renamed* Libertad, Argentina *and* Uruguay. *The* Libertad *was in service on the Buenos Aires to Europe route into the early 1970s, before switching to Antarctic cruises.*

Germany, which was banned from having an aircraft industry. Its aeronautical engineers, including the most famous, went not only to the USA or the USSR but to such countries as Spain, Argentina, India and the United Arab Republic. These nations were at different periods and for different reasons 'non-aligned' with the two great power blocs of the post-war era – the Soviet Union and the USA. Argentina, India and Egypt, the main part of the United Arab Republic, had been to different degrees British imperial territories, and in all three German aeronautical expertise was used more than British.

Under the nationalist-populist Perón regime, Argentina built a jet fighter, the *Pulqui*, which first flew in 1947. The name meant 'arrow' in the indigenous language, Mapuche, a sure sign of the nationalist impulse behind it. It was built under the leadership of one of France's great aeronautical engineers, Emile Dewoitine, on the run from France, where he was wanted for collaboration.[40] He had arrived in Argentina in 1946, via Spain where he had gone after the liberation of France, and would stay in Argentina till the late 1960s.[41] He was to be replaced in 1947 by an even more famous designer, Kurt Tank (1898–1983), the key designer at Focke-wulf. Tank had nearly gone to the Soviet Union. He had met with one of the Soviet aeronautical experts, Colonel Grigory Tokaev, who claimed to have put him off from journeying to Moscow to see Stalin. Tokaev would soon defect to the British, partly because he was unhappy with the Russian nationalism that Stalin was imposing.[42] From 1947 Tank designed and built the *Pulqui II* jet, which flew, with Nene engines, in 1950. It was, like the Soviet MiG15, descended from Tank's Ta 183. The *Pulqui II* never went into production and Tank and much of his team moved on to India. There they designed the supersonic Hindustan *Marut* fighter, in service from the 1960s to the 1980s: over 140 were built. This too depended on a British engine. India later collaborated with that failed pan-Arabic nation, the United Arab Republic (UAR), of Egypt, Syria and Yemen to design aero-engines for their national fighters. Again German expertise was central.

The UAR aircraft programme had started in Spain.[43] Spain saw autarkic development in aviation, in the 1940s and 1950s, again with German specialists.[44] Claude Dornier (1884–1969) worked for the CASA company in Madrid, designing light utility aircraft for the military, also later to be built in Germany. Willy Messerschmitt (1898–1978) went to Spain in 1951. First he developed a jet trainer, which could also be used in combat, and a good number were built. Egypt started producing them in the 1950s and some were still in service in the 1980s (they were called *Al-Khahira* (Cairo)).[45] Messerschmitt (with the collaboration of Ernst Heinkel) also built the H300 supersonic fighter which never went into production, and was further developed by the Egyptians through the 1960s, without success. It too depended on British engines. These non-aligned technologies proved not to be very significant. Spain obtained US aircraft from the early 1950s; and Egypt and India turned to the USSR, as well as other suppliers.

Foreign technology and socialism in one country

The Soviet Union provides a particularly startling case of autarkic development based on foreign technology. Socialism in one country, the central dogma of Stalinism, depended on foreign expertise. The Soviet Union, and thus the rest of the Soviet bloc (including China for a while), relied on processes, and sometimes in effect products, first developed in the capitalist countries, particularly in the USA. Ford was one of many companies that transferred their equipment, skills, personnel and products there. The USSR not only imported but built Fordson tractors, as it did Ford's Model A cars, and Model AA trucks. The tractors were produced in a plant in Kirov reconditioned by Ford, the cars and trucks in a large plant built in Gorky. The result of a deal signed with Ford in 1929, it was easily the largest vehicle plant in the USSR, producing nearly 70 per cent of output by the end of the 1930s, around 450,000 vehicles per annum. The Gorky plant is still the second Russian producer of cars, and the largest maker of trucks and buses.[46] There were two other plants for cars and trucks. The AMO factory in Moscow, rebuilt with US equipment, renamed ZIS and then ZIL, made cars and trucks to US designs. This plant was the parent of the Chinese First Automotive Works, formed in 1953, which made 1.28 million Jiefang (Liberation) trucks between 1956 and 1986, another remarkably long-lived machine which was itself a copy of the ZIL 150 4-ton truck.[47]

Apart from the production of Fordson tractors between 1928 and 1933, the USSR bought two entire new tractor factories from the USA, one for Stalingrad, the other for Kharkov, to make International Harvester 15/30 machines. This was the tractor which had replaced the Fordson on American farms. A third new factory made the tracked Caterpillar 60, called the Stalinets, in Cheliabinsk. Counting the Fordson plant, the USSR had four plants by the mid-1930s, each meant to produce 30–50,000 tractors per annum.[48] The USSR was to be tractorised with American-designed tractors.

The other great symbols of Stalinism also depended on American expertise. Many of the gigantic dams and hydro-electric projects, such as the Dnieper complex, depended on US experts, skilled workers, designs for plants and product, and vast quantities of equipment. The famous steel works at Magnitogorsk, built partly by kulaks thrown off their farms at the time of collectivisation, was a copy of a US Steel Corporation plant. At the peak of construction in 1931 there were 250 Americans, plus other foreigners, directing the work at Magnitogorsk, just as there were in many other places.[49] The US plant was built from 1906 in Indiana on a greenfield site near Chicago named Gary, after Elbert Gary, the then chairman of US Steel. Thus even the naming of factories and cities after important people had roots in the USA.

During the Second World War there was a wave of transfer of technology, though not of production equipment. After the war there was a second wave, covering everything from marine diesels and fishing boats, to the chemical industry. In the 1960s the USSR once more turned to the West for car models and plant. A deal with FIAT led to the supply of (largely American) plant for a huge new complex that would produce versions of the Fiat 124 and 125 at the rate of 600,000 per annum from around 1970. The resulting model, called the Lada in export markets, is still being produced today. The plant remains the largest car maker in Russia, churning out around 700,000 cars a year – at less than half the level of productivity of the main international firms. It was built in a new town on the banks of the Volga named Togliattigrad and was part of a giant scheme involving the building of the Lenin Dam on the Volga. The town was named after the head of the Italian Communist Party, Palmiro Togliatti, who had succeeded the imprisoned Antonio Gramsci. Both had studied and become politically active in Turin, home of FIAT; an essay written in prison by Gramsci was to be the source of the term ‘Fordism’ for the left at the end of the twentieth century.

The Soviet Union was a poor country. The rate at which it took in foreign technology and industrialised itself was remarkable, as of course was the human cost it was forced to pay by Stalin. Its ambition was not merely to emulate, but to create a new and superior society, more innovative and more capable of using new technologies than crisis ridden, uncoordinated capitalism. The planned economies, with no significant private ownership, and no competition from capitalist enterprises for very long periods, would prove superior, it was claimed. From 1957, following the launch of Sputnik, many non-communists, indeed anti-communists in the West, came to believe that the Soviet Union had indeed cracked the problem of innovation and use of new technology. Khrushchev's famous declaration in the early 1960s that the Soviet Union would overtake capitalism was not a personal exaggeration but an expression of a long-standing and deeply felt interpretation of the likely course of history. Yet despite vast investments in R&D the Soviet Union and its satellites did not lead the world into a new technological era. Generally the Soviet Union lagged, and that lag increased in the 1970s and 1980s. The Soviet historian Roy Medvedev plausibly claimed that Lenin would have been surprised to find that the USSR had not overtaken the capitalist world in technology by the 1980s.

The classical Soviet view was that there was one technology, what mattered was the context in which it operated. It made all the difference in the world, they claimed, that although Soviet workers worked under the same division of labour as capitalist workers and were paid by the piece, they (indirectly) owned the means of production. Yet one finds some suggestions that Soviet technology took a different course from capitalist technology. Notably, it is argued that there was a particular tendency towards gigantism, the most recent expression of which is the Three Gorges dam in China. That seems doubtful as similarly gigantic projects can be found in the USA; indeed the Soviets were inspired by them. However, there may well have been much more pointless gigantism, such as the famous case of the White Sea Canal, extending for over 200km from Leningrad to the White Sea. Though built in the early 1930s, and still open, it has hardly been used. It took more than 100,000 workers to build. Most were convicts, and most of them apparently died during its construction.

After 1945 the most technically advanced part of the Soviet bloc was not the Soviet Union but the German Democratic Republic. And from here came 'group technology', trumpeted as a specifically socialist technology. It involved the grouping of work of particular types of machine in batch production to increase its efficiency. The idea was to analyse components and set up groups of machines (cells) to produce a range of related components. Group technology was not a thing, but a means of organising specific forms of production, and one which turned out to be completely compatible with capitalism. The technological leadership it was hoped would derive from this never materialised.[50] The GDR is also known for a distinctive car, the Trabant, another exceptionally long-lived machine. It had a synthetic body, and a 2-stroke 500cc engine. It was in production in the same factory from 1957 to 1989; around 3 million were built, with maximum output of 100,000 units per annum in 1970s.[51] Yet it was not copied even within the Soviet bloc. It was clearly a particular response to all sorts of shortages of materials, not a brave new venture in car technology. The GDR also provides one of the few cases where it has been shown that a planned system clearly led to rapid diffusion of technology: the GDR's health system pioneered the widespread use of a Swiss technique for dealing with broken bones.[52]

Nations versus firms

The greatest transnational institutions of the twentieth century were not the Second, Third or Fourth Internationals of the socialists and communists, or bodies such as the League of Nations or the United Nations. They were firms which operated in more than one nation – the so-called 'multinationals' – and among them were most of the world's largest firms. Not only do some of them have larger turnovers than some small states, but many were founded, and operated multinationally, before the majority of modern nation-states were formed.

Even before the First World War, Ford, the Chicago meatpackers, the major electrical firms such as GE, Westinghouse and Siemens, major armourers such as Vickers, and the Singer Sewing Machine company operated around the world.

The technological capacities of firms, national and multinational, need to be distinguished from those of their home nation. The photographic industry exemplifies the need to look at firms and their histories. At the end of the nineteenth century, knowledge about the photographic process was concentrated in Europe, and yet by 1914 a US company, Eastman Kodak, dominated photography in most countries of the world. Kodak was to compete against different kinds of firms. In Britain, specialised photographic firms, merged into Ilford Limited in the 1920s, were a reasonably strong alternative. In Germany and elsewhere, the chemical giant IG Farben, under the trade name Agfa, was the key competitor. Each firm had different technical resources and innovated different kinds of colour photographic processes. IG Farben, the world's leading dye firm, was able to make a film called Agfacolor in which it had embedded most of the complex reagents that were necessary to process the film. The film could thus be processed by amateurs and chemist's shops. Kodak developed expertise in dyes and fine chemicals during the Great War, and it used this to produce Kodachrome, a film that relied on very complex processing, which had to be done by Kodak in its existing network of processing facilities. Kodachrome and Agfacolor, introduced in the 1930s, were 'subtractive' processes. By contrast, the Dufay process, promoted by Ilford, was 'additive' – it essentially created three different photographs, each occupying a third of the image, a process which required no expertise in dye chemistry. By the 1930s Britain had that expertise, Ilford did not.

The early history of television provides another interesting case, though the key connection is not to Germany as in the case of synthetic dyes, but to Russia. Two key technical leaders, Isaac Schoenberg of EMI and Vladimir Zworykin of RCA, were both Russian, and had both studied with the Russian pioneer, Boris Rosing, at the Imperial Institute of Technology in St Petersburg, before the Great War.[53]

Zworykin arrived in the USA in 1919; Schoenberg in Britain in 1914. But the key organisation at the centre of this activity was the Radio Corporation of America, Zworykin's employers. It had investments and technical connections in two key European firms which supplied the modern TV equipment, EMI in Britain (Schoenberg's employers), and Telefunken in Germany. The Marconi–EMI system developed in Britain was directly derived from related RCA work. More intriguingly still, RCA was to transfer a great deal of technology to the USSR before the Second World War, including television, such that RCA technology was used to broadcast TV in the USSR before the USA.[54] Britain, Germany, the USA and the Soviet Union, all developed television in an experimental form at the end of the 1930s, based on RCA technology. It is worth noting that with the exception of what happened in the USA, television, like broadcasting generally, was under the direct control of the state in these countries.

Nation, empire, race

In thinking about the relations between the global and the national in the history of twentieth-century technology it has been obvious that things, expertise and experts crossed political boundaries all the time. The importance of these boundaries changed, and radically so, over time. The boundaries themselves changed too. Nations were hardly eternal. More than that, multi-national states were hugely important. The USSR was a multi-national state, half its population was non-Russian; its 'national' anthem had been, until 1943, the 'Internationale'. Trans-national political commitments were also important. Italian communist engineers went to the Soviet Union in the 1920s. While post-war Spain had many German and Italian technicians working there, there were many Spanish experts elsewhere. There were Spanish aeronautical engineers working in the French aircraft industry in Toulouse who would not have wanted, or been able, to work in nationalistic and autarkic Spain.[55] Most important in this respect were the close links between the Soviet Union and China between 1949 and 1960. One of the most bizarre was the political link between China and Albania in the 1960s and 1970s following the decisive break in relations between China and the USSR. Albania relied on Chinese technology; the common language was the Russian dominant in the Soviet Union, the source of much of the Chinese technology.

The great empires of the twentieth century were also hugely important trans-national and trans-ethnic political and technological entities. Far from being throwbacks to the past, empires were intimately associated with particular new technologies, for example long-distance radio broadcasting, aviation and tropical medicines. They lasted into the 1950s. But empire not only left a technological mark, post-imperial relations did too. One finds few French cars in India, or British cars in Tunisia.

National and imperial boundaries were often radically less important than racial boundaries within nations and empires. For many European intellectuals a sense of scientific and technological superiority was crucial.[56] Much discussion of inventiveness in particular was associated with racial and cultural analyses which transcended nations. In the United States blacks were deemed by whites to be uninventive, to the extent that a pioneering sociologist of invention noted that it is 'inadvisable to count in the colored populations of the United States and the British Dominions' in computations of relative national inventiveness 'since these people do not figure in invention'.[57] Another analyst of the 1920s argued that the USA had low per capita inventiveness because 'the United States have a dilution in the negroes in our population.'[58] If women had been distributed unevenly around the world the same argument would have been made about them.

In the USA the armed services were racially segregated, and the black formations were generally of very low status. There were, for example, no black pilots in the US forces in the interwar years. However, from 1941 there was segregated training for black pilots who would go into segregated squadrons; only after the war were US forces officially desegregated. Bell telephone maintained segregation and did not employ black telephone operators pre-war; after the war they did so only because the labour market forced them to.[59] While in the interwar years there were large numbers of black car mechanics and taxi drivers, many whites held blacks to be bad drivers with no mechanical sense.[60] No place in the world is more symbolic of the new technologies of the late twentieth century than 'Silicon Valley' in California. Perhaps 80 per cent of the production workers belong to ethnic minorities; and the great majority were recent immigrants (many of them Spanish-speakers) to the USA, and are women.[61] Many of the technical staff are South and East Asian.

Sometimes, of course, some have celebrated what they see as their lack of invention by their own community. The celebrated Martinican poet of negritude, Aimé Césaire, lauded

> those who invented neither powder nor the compass
> those who have never been able to tame steam or electricity
> those who have explored neither the seas nor the sky
>
> Eia for those who have never invented anything
> for those who have never explored anything
> for those who have never subjugated anything.[62]

But many others, including the *dependencia* theorists, lamented, for example, that '*La diosa tecnología no habla español*', which meant Spanish speakers were not notable in the world of research and invention.[63] '*Que inventen ellos*,' said the Spanish essayist and rector of the ancient University of Salamanca, Miguel de Unamuno, before 1911. The phrase has achieved notoriety among those who want to see invention flourish in Spain, and indeed no rector of the University of Salamanca would say it today. A document prepared by a 'western intellectual' around 1960 claimed that Russian and 'Eastern Slavonic nations' were 'much less inventive and imaginative' than the Anglo-Saxon nations. But the Soviet bloc was inventive in many ways and *Homo sovieticus* was not a slav.[64]

These comments reflect very substantial differences in participation in elite inventive activities. Only sixteen non-whites have won Nobel prizes in science and medicine, but not one has been of African descent, despite the fact that the USA, the clear leader in the Nobel prize league table, has a very large African-American population.[65] Very few Spanish speakers have won science or medicine prizes, while Spanish-speaking writers and poets from many nations have been garlanded with the Literature prize. Latin America, Africa and some parts of Asia produce few patents, while most of the Northern Hemisphere, including Japan and Korea, turns them out in prodigious quantities. Uruguay and Brazil give two patents per million population to residents, while Finland gives 187. In the USA there are worthy listings of African-American inventors; the fact that such lists are manageable points to the small numbers involved.

Racial and cultural differentiation was far from confined to invention. In the great empires there was a profoundly racial economy of technology in use. Empire created rich enclaves for European colonisers in colonies and near-colonies, with motor cars, telephones, electricity, running water, cinemas and so on. These were places such as the international settlements in Shanghai, Carthage/Tunis, Casablanca, Ismailia (on the Suez Canal), New Delhi, Singapore, and others. On a smaller scale, enclaves for white engineers and workers from the rich world were dotted around the poor world. Thus American employees of the United Fruit Company lived in special compounds in the company's banana plantations in South and Central America; while American and other engineers had special housing and facilities in the USSR in the late 1920s and early 1930s.

Within imperial territories race was central to social organisation. In all the places where white technology went, white technicians were in control. The pilots who steered ships through the Suez Canal were British and French, not Egyptian. On the vast Indian railway network, the great majority of its senior engineers were white British. In the interwar years whites born in India became more important, as did, at lower levels, mixed-race 'Anglo-Indians' or 'Eurasians', of whom there were over 100,000. Into the 1930s there were still many British-

17. India's tryst with its modern destiny shown on a postage stamp commemorating India's independence from the British Empire on 15 August 1947. India later designed and built jet fighters rather than the civil transports shown on the stamp.

born locomotive drivers among the large number of Anglo-Indian train drivers. In the Dutch East Indies (later Indonesia) the railway equipment, down to the rails, was imported from Europe. Until the end of the colonial era, only some parts of carriages and the sleepers (made of teak) were local. At least as late as 1917–18 'not a single clerk, station master or machinist was a non-European'.[66] Motor vehicles were much more open to natives.[67] In 1935 the number of native car owners was just below the number of European owners, and just over the number of 'foreign oriental' owners; however, there were twice as many licensed native drivers as Europeans, who presumably were chauffeurs and taxi drivers.[68]

There was a particular racial order in the vast British merchant marine that served in India and elsewhere. It depended to an extraordinary degree on 'lascars', seamen recruited from the Indian subcontinent. In 1928 there were more than 52,000 lascars aboard British ships; 26 per cent of all crews, and 30 per cent of engine-room crews. Special regulations applied to their employment, for example in voyages through cold seas.[69] There were divisions along geographical, religious and ethnic lines: Catholic Goans served in ships' galleys and acted as waiters and servants; Muslim Punjabis dominated in the engine room; and deckcrews, both Muslim and Hindu, came from many places.[70] Needless to say these British ships were all officered by white British mariners.

The Indian army, officered very largely by white officers, was given older and less powerful equipment than all-white formations of the British army.[71] The pre-war Indian Navy and Air Force (created 1933) were tiny. In India non-technical higher education was much more widely available to Indians than technical education; British technical education was much more technical than its Indian offshoots.[72] When they took over Malaya from the British, the Japanese boosted technical education for Malays and Indians as well as local industrialisation.[73]

It is little wonder that the end of imperialism was so important to national technological development, and indeed that nations emerging out of empires felt a strong need not only to develop national technologists but national technologies too.

Asia and techno-nationalism

Japan represents the great twentieth-century exception to white dominance in technology. A strong, imperial state in the early twentieth century – among its colonies were Taiwan, Korea and, for many years, much of China – it was a serious technological power by the interwar years. The so-called Prussia of the East replicated Britain with its great navy and cotton textile industries of the interwar years. Even in defeat after the Second World War, Japan kept control of its economy, and Japanese-owned and -controlled firms not only imported technology, but began to generate technologies of their own. Japan rose to be the second performer of research and development in the world by the 1970s. At the same time its car and consumer electronic industries posed a serious threat to North American and European companies.

In this respect the Japanese were much more successful than the Soviets, another power which had spend a great deal on importing technology and on research and development.

The Chinese case is quite different from the Japanese, or indeed from the Korean and Taiwanese cases. Although nationalism was and remains a very important part of communist politics in China, the opening to the world since the late 1970s has not led to the development of a powerful local technological infrastructure. Most of China's exports, especially in the electronic sector, come from foreign-funded and foreign-owned enterprises, rather than either state-owned or locally privately owned ones. In any case, much of China's exports are low-tech: textiles, toys and all sorts of other cheap goods. If Wal-Mart were a country, it would be China's eighth largest trading partner. There is however one distinctive aspect of foreign enterprise in China – it is mostly eastern rather than western. It comes from Japan, and from the so-called overseas Chinese. The Chinese minorities in Malaysia, Indonesia and the Philippines have been central to industrialisation and technical development in these post-imperial nations. Political structures, and ethnic and linguistic links are interacting in complex ways.

Yet nationalism, and national control, is far from dead in the new globalised China. The internet, supposedly necessarily an agent of internationalisation, is thoroughly controlled in China. Search engines do not recognise words, such as 'democracy', which the government does not like. Sites cease to exist when access is attempted from China. China also pursues some very old-fashioned techno-nationalist enterprises. In 2003, more than forty years after Yuri Gagarin became the first man in space, China put a Shenzhou-5 capsule into orbit carrying a man.