The Hidden Integration of Eurasia: East–West Relations in the History of Technology

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Abstract: "East" and "West" have long been prominent categories in the history of technology. The historical literature that claims to deal with comparisons or connections between East and West from a technological point of view is rich and fascinating. Yet, so far there has been no attempt to succinctly summarize or synthesize the main findings. This article takes a first step towards such a synthesis. It does so by addressing technological interaction between three broadly defined geographical regions: (1) Western Europe and North America; (2) Eastern Europe, Russia and Central Asia; and (3) the non-Russian Far East. The article suggests that East–West studies in the history of technology can be divided into three sets, which would benefit from greater interaction with each other: studies of East–West and West–East technology transfer; studies comparing the evolution of Eastern and Western technological levels and technological "styles"; and studies of large technical systems that materially interconnect East and West.

Keywords: *China, East–West relations, Europe, large technical systems, Russia, technological style, technology transfer*

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1. Introduction: East and West in the history of technology

"East" and "West" have long been prominent categories in the history of technology. Although admittedly vague, the concept pair has been crucial in generating fundamental research questions such as why the Industrial Revolution occurred in the "West" and not in the "East," and whether—and if so, why—"Western capitalist" countries were more successful in fostering technological progress than "Eastern communist" countries during the Cold War. With the collapse of communism in the former Soviet Union and East-Central Europe in 1989–1991, the spectacular rise of Japan and then China as a "technological superpowers" in recent decades, and the resurgence of technology as a political tool in twenty-first-century confrontations between China, Russia, and the West, the interest in the differences, similarities, and dynamics of technological interaction between East and West is today greater than ever.

The historical literature that claims to deal with comparisons or connections between East and West—taking into account the multiple interpretations of the two—from a technological point of view is rich and fascinating. Yet, there has so far been no attempt to succinctly summarize or synthesize the main findings. The purpose of this article is to take a first step in that direction. It does so by bringing together several strands of research in the history of technology that most scholars have tended to treat as separate domains but which, in our view, deserve to be treated as variations on one and the same historical theme. The article thus seeks to make existing works in the history of technology communicate with each other.

The article starts out by briefly discussing the concepts of East and West and their significance in historical research, a major argument being that it would be better to split East and West analytically into (at least) three more or less distinct geographical regions, which interact with each other. It then identifies three types of studies in the earlier literature on East and West in the history of technology: studies of East–West and West–East technology transfer; studies comparing the evolution of Eastern and Western technological levels and technological "styles"; and studies of large technical systems that materially interconnect East and West. The subsequent sections discuss each of these three literatures, seeking to identify the main results, trends, and controversies. Finally, the article discusses the ways in which the three forms of interaction can be seen to have interacted with each other historically.

2.   Where is the West? Where is the East?

East and West as cultural-geographical categories are notoriously difficult to define, and there is no agreement in the literature about their physical extent. While numerous scholars have claimed to be studying phenomena relating to "East" and "West," they have had very different geographical areas in mind. Thus, one region which may be considered part of the West in one study may well be defined as belonging to the East in another study. The simplistic thesis that "east is east and west is west" exists only in poetry.

In many cases the usage of the two concepts is deeply contradictory. For example, for Cold War historians comparing the "capitalist West" and the "communist East", countries such as Japan, South Korea, and Australia belonged to the West, while Cuba belonged to the East. Moreover, the socially constructed East–West geography is dynamic and prone to change over time. Following the politically inspired interpretations of East and West in the post-Cold War era, for example, it has been common to point to a process by which some East-European countries are transformed into West-European countries. Or, as politicians and historians alike in these countries typically put it, they "returned to the West" after 45 years of Soviet dominance (e.g., Smith, 2000; cf. Misa & Schot, 2005).

The most difficult country to place is probably Russia. Europeans usually regard Russia as an "Eastern" civilization, but at the same time it is rarely regarded as Asian. The Russians themselves typically think of their nation as a unique cultural and geographical entity that does not really fit the East–West dichotomy. Recently it has become popular both in Russia and Kazakhstan to brand their nations as "Eurasian," thus signifying that they qualify as both Eastern and Western polities and cultures (see, e.g., Laruelle, 2008; Dave, 2007). In the history of technology, some scholars have successfully included Russia in studies of "Europe," but few—if any—have tried to argue that Russia is part of the "West" or "Western Europe."[1] From the East-Asian horizon, however, Russia is often thought of as a Western nation, at least as far as ethnic, religious, and linguistic factors are concerned. Moreover, a commonly used

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[1]   See, in particular, the book series *Making Europe: Technology and Transformations, 1850–2000* (edited by Johan Schot and Phil Scranton and published by Palgrave Macmillan, 2013–2016).

Chinese term for Central Asia (or, in a more narrow definition, the province of Xinjiang) is "the Western Regions" (*Xiyu*, or西域).[2]

Given the diffuse nature of "East" and "West" as cultural-geographical notions, it is not surprising that studies of the relations between the two have generated divergent geographies of interaction. There are at least three well-established geographical foci in earlier research on East–West technological interaction:

- Firstly, there has been considerable interest in **Western Europe's and North America's relations with China, Japan, and other distinctly Asian nations**. This research theme has been of great interest to historians of the Arab world and of ancient China and, more recently, to scholars studying the modernization of the Far East in the industrial era, starting roughly in the late nineteenth century and continuing up to today.

- Secondly, many historians of technology have taken an interest in **Western Europe's and North America's relations with Eastern Europe, Russia and Central Asia**. When the Tensions of Europe Network recently arranged a major conference devoted to the study of "Technology and East–West Relations," for example, it was essentially this definition of East and West that the organizers had in mind.[3] East–West relations in this sense became especially intriguing during the Cold War, in which East and West were typically used as synonyms for the communist and the capitalist world.

- Thirdly, some scholars have focused on the relations between **Russia (or the Soviet Union) and non-Russian Asia**. These relations became a factor starting with Russia's expansion into Siberia from the sixteenth century onwards. A breakthrough occurred when Russian industrialization, in the late nineteenth century, spread to the old Silk Road oases in Central Asia and to the Pacific coast. They intensified further during the Cold War, although in the case of China the 1960 Sino-Soviet split led to a near-total break in relations. Russian-Asian relations are generally not explicitly termed "East–West" relations, but there is good reason, as we shall see, to view them precisely as such.

With few exceptions, historians of technology have viewed the three geographical foci above as constituting separate research fields. Accordingly, few historians

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[2]   For a useful overview of current Chinese perceptions of Europe, see Jing Men (2006), who, among other things, notes that it is common in China to view the EU as an association between "Christian countries". For a historical overview of Russia's perceptions of China, see Lukin, 2003.

[3]   *4th Tensions of Europe Conference*, Sofia, Bulgaria, June 17–20, 2010.

of technology have addressed more than one of them. From a conceptual and theoretical point of view, however, it may be useful to view them as variations on one and the same theme. The three have a lot in common. For example, Russia and China faced similar difficulties when trying to master Western industrial technology, and technology transferred from Russia to China was sometimes only part of a longer process that started with the same technology being transferred from Western Europe to Russia.

Hence, the argument here is that East–West relations must be viewed in an all-encompassing Eurasian perspective. In the rest of this article we will discuss East–West relations mainly in the form of Western–Russian, Western–Far-Eastern and Russian–Far-Eastern relations, where we use the notion of the "Western" world in an admittedly sweeping way to denote Western Europe and North America. For the sake of simplicity, we have generally refrained from taking into account the Middle Eastern region and South and Southeast Asia.

3.   Forms of interaction

Geography aside, what forms have East–West relations taken? Judging by the existing history of technology scholarship, it is possible to discern at least three major themes:

(1) *Technology transfer*, referring to a process by which Western and Eastern actors acquire technologies and technological knowledge (sometimes embodied in engineers and other experts) from "the other";

(2) *Convergence and divergence of technological styles*, referring to a trend in which Western and Eastern technologies and ways of dealing with them become more and more (or less and less) similar over time;

(3) *Infrastructural integration*, referring to technology-intensive, material interconnections between East and West in the form of large technical systems for transport, communications, and energy.

The extent to which these interactions have actually occurred—and when—is an empirical question. In the following sections we sketch the most important patterns in each of the three subfields. Taken together, they can be said to reflect the "hidden integration"—to borrow a term that so far has mainly been used in the context of European history of technology—of the vast Eurasian continent. Such integration, in which technology is viewed as central to human undertakings,

differs from and challenges—while also offering a compliment to—more "visible" or well-known transnational integration (and disintegration) histories, such as the narratives developed by political and economic historians. Accordingly, one ambition here is to point to the relevance of history of technology to a broader community of scholars engaged in the study of East–West relations.

4. Technology transfer

Literature on technology transfer is the richest of the three literatures discussed in this essay. It is particularly rich when it comes to studies of the Cold War period, although in that case much of what we know today is the result of the work carried out not by historians but by social scientists studying what at the time were still contemporary phenomena. The Cold War was a golden age for students of "the other's" technology, because governments generously funded research that aimed to unveil the dynamics of innovation on the other side of the Iron Curtain. Knowledge of the other's technological culture was seen to be of direct military significance, while at the same time governments took interest in alternative—and potentially superior—ways of organizing and managing the innovative process. This, of course, continues to be an important research topic in today's social studies of innovation. At the same time a new generation of historians in Western Europe, Central and Eastern Europe, and East Asia have, during the past two decades or so, taken renewed interest in technology transfer as a historical phenomenon.

The main focus in the technology transfer literature has been on the transfer of technologies—in one or the other form—from "West" to "East", at least as far as the modern era is concerned. However, there was a time when technologies were mainly transferred in the opposite direction. Much of medieval Europe's technological progress, for example, built on inventions that, to borrow Lewis Mumford's lyrical phrase, "were windblown seeds from other cultures." (Mumford, 1934, p. 108; cf. Sivin, 1982) Egypt, Persia, and the Arab world all provided important inputs to European technological development. Of interest here is also Europe's possible acquisition of some of Ancient China's "great inventions", such as paper, the magnetic needle, and gunpowder. The extent and importance of this interchange—including the issue as to whether it ever took place at all—has been subject to interesting disputes. Conventional Chinese history of technology narratives usually point to an important role of Ancient

Chinese technologies not only for China itself, but for foreign countries as well. Pan Jixing, for example, writes that "more than one hundred fundamental [Chinese] discoveries and inventions had an influence on world science and technology" (Pan, 2002). Western scholars have questioned this. The French historian Bertrand Gille, for example, argued that, on the one hand, "perhaps the contribution made by China to the Western world […] has been over-emphasized," and on the other, "the practice of borrowing Western techniques by China has not been emphasized enough" (Gille, 1986, p. 382).

Much better documented is the history of technology transfer between Western and Eastern Europe. Historians of technology, economic historians, and historical geographers have documented how, from the Middle Ages on (or even earlier), an impressive number of technologies spread from Western Europe's technological hotspots with seeming ease to nearly all corners of Europe, including many regions that nowadays are commonly thought of as belonging to East-Central Europe, such as Hungary, Poland, and the Baltic countries (see, e.g., Pounds, 1979). Initially the territories of what now constitutes Russia, Ukraine, and Belarus were also part of this dynamic process. Following the Mongol invasion of these lands in the thirteenth century, however, they became largely isolated from the West. An important consequence was that Russia was not able to profit more than marginally from Europe's technological advances during the late medieval era. On the other hand, the Mongol rule generated opportunities to acquire technologies from Central Asia. As a result, scholars have often disagreed about the geographical origins of technologies adopted by Russia. It is not clear, for example, whether the well-documented appearance of firearms in Russia from the late fourteenth century was the result of technology transfer from Europe, from Central Asia or the Far East (Esper, 1969).

In the sixteenth century, by which time Russia had been liberated from the Mongol rule, Ivan IV ("the Terrible") actively sought to attract West-European technology and technical experts to Muscovy so as to catch up with the Europeans. The actual impact of these attempts is subject to debate. In the seventeenth century, Western Europeans were invited to Russia in larger numbers, particularly from Holland, England, and Germany (Normann Waage, 1992, pp. 38–43). Yet the overall impression is that technology transfer from Western and Central Europe to Russia gained momentum in earnest only during the reign of Peter the Great. Peter famously set out to acquire the latest shipbuilding and other technologies from Holland and elsewhere. The process accelerated further in the early industrial era and in particular after the Crimean War (1853–1856), which

alarmed the Russians about their technological inferiority in a number of fields—not only in explicitly military areas such as weapons, but also in communications and transport, which increasingly were defined as strategically important. Up to the 1917 Russian Revolution this process continued unabated.

Pre-industrial Russia's relations with China are a different matter. Much like Western Europe, Russia started to become aware of China in earnest only during the eighteenth century (Lukin, 2003, p. 3). Historians of Central Asia have pointed to a quite dynamic technological development in the borderlands between Russia, China, Mongolia, and Central Asia from these times. An interesting case is the Zunghar State in what is now northern Xinjiang, whose engineers "obtained gun-casting and cartographic technology from Russians and Swedes formerly in Russian service." Sweden was Europe's leading iron manufacturer at the time, and some of its skilled technicians ended up as Russian prisoners of war following the Great Northern War (1700–1721). Thanks to their skills they were able to continue their engineering careers in Russian service and, as the example shows, even migrate further east into territories now forming part of China (Millward, 2007, p. 89). This illustrates what for some time might have been a major pattern of Western technology transfer to China by way of Russia.

West–East technology transfer took on a completely new scale from the late nineteenth century. The focus was now almost exclusively on the transfer of Western technologies to Russia and Asia, not in the other direction. However, scholars have emphasized that technology transfer in the industrial age has to be put into a longer historical context. In the case of the Far East, some transfer of technology can be traced back to arrival of the first European ships in the sixteenth, seventeenth, and eighteenth centuries. It has even been argued that technology transfer from the West helped the Manchus to come to power in China in 1644, paving the way for the Qing era in Chinese history. Moreover, Japan skillfully acquired a range of Western and, in particular, Dutch technologies as early as in the Tokugawa period (ca. 1600–1868). This experience made the Japanese well-prepared for the much more intense West–East technological interactions that became possible after the "opening" of Japan—a term that has been questioned—and the transition to the Meiji era (Gooday & Low, 1998).

In many cases, attempts to transfer early industrial-era Western technologies to China and Japan failed. For example, the first attempt to establish a modern Chinese iron works in 1885, based on imported British technology and located at Qingxi (清溪) in Guizhou Province, failed as a consequence of insufficient knowledge of technical details and the unsuitability of the local coke and coal

that was to fuel the facility. It failed despite the fact that the managers had far-reaching experience of working with Western technologies in other fields and enjoyed close contacts with British manufacturers. A corresponding attempt to establish Japan's first modern iron works, also based on British technology and located at Kamaishi, also failed due to problems with the fuel. Twenty years later, however, the Chinese had learned their lesson and were able to successfully acquire British steelmaking technology (Fang, 2012; cf. Wang, 2010).

The transfer of Western technology to China saw a breakthrough after the 1894–1895 war with Japan. Bart Hacker has argued that China's humiliating defeat in this war was not a product of technological backwardness as measured by the quality of weapons; rather, it resulted from a belief that "the West's military technology could be detached from Western culture as a whole." (Hacker, 1977, pp. 51–52) This view could not be sustained after the war. The central government, which had earlier been very restrictive in allowing Western technologies to flourish in the country, was now weakened, and it became easier for Chinese engineers and businessmen to forge alliances with Western experts and investors. The result was an unprecedented industrialization boom that, in spite of extreme political turmoil in the early twentieth century, continued right up to the outbreak of the next Sino-Japanese War in 1937 (see, e.g., Chang, 1993; Wang, 2012). The two decades preceding Japan's full-scale invasion of China, and in particular the last ten years of this period, became an extremely dynamic period of industrial development and technological progress. China here essentially followed the example of Japan, which "eagerly imported technologically advanced machinery and transport equipment from the West" so as to improve their industrial competitiveness. China seemed to be going through what economic historians call "import-substitution industrialization," in which technology transfer was at the very heart (Sugihara, 2004).

After 1945 and the onset of the Cold War, East–West technology transfer patterns shifted again. While Japan was quickly and strongly integrated with the Western economic system, being granted access to Western technology on a large scale, the Communist victory in the Chinese Civil War and the formation of the People's Republic in 1949 led to near-total isolation of China from the capitalist world. The Soviet Union became the country's only major partner, and it willingly assisted in China's further technological development. Soviet technology transfer came to play a crucial role for Red China's industrialization up to 1960, a prime example being the Soviet Union's assistance in setting up a sprawling Chinese

petroleum and petrochemical industry (Hu, 2013).[4] Following the 1960 Sino-Soviet split, this dynamic interaction came to a halt. The 1960s became China's most isolated decade, and technological self-sufficiency became a key slogan under Mao. The gradual opening up of the People's Republic in the 1970s, however, invigorated a new era of highly dynamic technology transfer from Japan and other East Asian economies, the United States, and Western Europe—in a way that was absolutely central to the Communist Party's modernization drive.

Western technology transfer to the Soviet Union, meanwhile, had seemed to gain momentum during the Second World War through cooperation between the three Western Allies (Britain, France, and the United States) and the Soviet Union. The technologies that were transferred during the war—and the war "trophies" that the Red Army brought home from Germany and Central Europe—played an important role for further technical progress in the Soviet Union during the first postwar decade. However, the Cold War changed the prospects for East–West interaction. The NATO countries came together in setting up the Coordinating Committee on Export Controls (CoCom), a regime that began to be loosened, however, as early as in the late 1950s. The erection of the Berlin Wall in 1961 and the Cuban Missile Crisis in 1962 led some to suggest a tougher embargo policy vis-à-vis the communist world, but the interests of Western technology developers in conquering Eastern markets made such proposals controversial. In the end, the period from the mid-1960s became a period of far-reaching détente in the relations between the capitalist West and the Soviet bloc. Far-reaching technology transfer took place. Yet, as emphasized in the literature, the transferred technologies often failed to form a basis for further, internally-driven innovation in the centrally planned economies of the East (Paliwoda & Liebrenz, 1985; Schaffer, 1985; Bertsch, 1986; Sandberg, 1989; Hanson 2011; and many others).

The opening of state archives in the former communist countries has broadened the views of Cold War technology transfer. For example, it has become possible to show how, in a few cases, technologies developed in Eastern Europe were successfully transferred to the West. A main source of such developments appears to have been Czechoslovakia, which in the interwar era had earned a reputation as one of the world's most advanced industrialized nations. As Karen Freeze has shown, although the new postwar situation made it difficult for the Czechs to retain their prominent position, their inherited competencies in combination with effective management and international partners—Britain was particularly

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[4]   For an overview of Soviet-Chinese technology transfer in the early Cold War era, see Zhang *et al.*, 2010.

important—made it possible for a few radical innovations such as the open end spinning machine to conquer world markets (Freeze, 2007). In the same vein, Riikka Nisonen-Trnka (2011) studied the transfer of Czech contact lens technology to the West. Another fascinating case is Eglė Rindzevičiūtė's (2011) study of what could perhaps be labeled "East–East transfer" of computer technology from Soviet Russia to Soviet Lithuania. But recent archive-based research has also supported the earlier view that technology transfer from the capitalist West was extremely important for industrial and economic development in the communist East, with several studies indicating that the intensity of interaction for this purpose was even higher than previously thought (e.g., Autio-Sarasmo, 2011).

Another highly interesting recent strand of research on Cold War technology transfer has focused on the transfer not only of technologies as such, but of the broader social contexts in which actors operated. One interesting case here is Lewis Siegelbaum's study of the "Soviet automobile", in which not only vehicles are at stake but rather the entire societal paradigm of what contemporaries in the Soviet Union simply referred to as "Detroit" (Siegelbaum, 2008). Another is Elena Kochetkova's analysis of Soviet acquisition of Finnish forestry technology, which in the end came to include not merely equipment, technology and expertise, but also "a changed view of Soviet workplace management and everyday practices" (Kochetkova, 2016).[5]

5.   Convergence and divergence of technological styles

The second dimension of East–West technological interaction refers to the convergence and/or divergence between Eastern and Western technologies. Convergence and divergence here should be understood not only in terms of the relative technological "level" of countries and regions, but also their differing technological "styles."[6]

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[5]   A further aspect of technology transfer worth mentioning concerns the ways in which educational institutions have historically contributed to or facilitated the transfer process. This, however, goes beyond the scope of this article.

[6]   Technological style can refer to the ways in which a country or region specializes in certain technologies; how its solutions to given problems differ from the solutions developed elsewhere; how the innovative process is organized and regulated; etc. For a discussion of technological styles, see Hughes, 1983; for the related concept of "styles of innovation," see the special issue on "Differences in 'Styles' of Technological Innovation," Technology Analysis & Strategic Management, vol. 10, December 1998.

As for the pre-modern period, the relative technological levels of Europe, the Middle East, the Indian subcontinent, China, and Japan have long been subject to dispute. Following the pioneering work of Joseph Needham, whose *Science and Civilization in Ancient China* started to be published in the 1950s, Western sinologists and Chinese historians of technology nowadays tend to view ancient China as a technologically more advanced civilization than pre-modern Europe and Russia. Pan Jixing, for example, writes that "more than half of elementary discoveries and inventions on which the rise of the modern world depends originated in China" and that "China kept a leading position in the field of technology during long ages" (Pan, 2002, p. 1). Nathan Sivin (1982, p. 46) points to "European inferiority in technology over a span of fourteen hundred years". Some European scholars disagree. Bertrand Gille, for example, argued that Europe and China were more or less at the same technological level in pre-modern times.[7]

Most historians agree that Western technology eventually reached a higher level than that of all other civilizations, but there is disagreement about the timing. Many historians of technology regard the year 1500 as the rough starting point for a notable divergence in terms of European and non-European technological levels. By contrast, Kenneth Pomeranz, in a famous work, argues that it was only in the nineteenth century that the "Great Divergence," as he calls it, intensified in earnest (Pomeranz, 2000).

Russia and most of Eastern Europe, for their part, never appear to have assumed global technological leadership in pre-modern times. Sometimes technological backwardness even seemed to define "Eastern Europe". Before the Cold War, for example, the Czech lands were widely recognized as belonging to the technologically most advanced regions of Europe, a fact that appears to have contributed to the perception of these lands as "Western" European territories. Only with the inclusion of Czechoslovakia into the Soviet sphere of influence in 1948 did this perception change. It is also interesting to observe that the three Baltic countries—Estonia, Latvia, and Lithuania—have actively used their relative technological sophistication as an argument in debates where their "Westernness" has been at stake—both during the interwar era and in more recent, post-Soviet times (see, e.g., Tiits *et al.*, 2006).

During the Cold War the Soviet Union had high technological ambitions, and

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[7] Gille writes, for example, that Chinese technological development does not "appear to differ radically from what we have seen in Greece and Rome, or elsewhere in the Middle Ages in Europe" (Gille, 1986, p. 384).

the 1957 "Sputnik shock" generated fears in the West that the "communist East" might be about to overtake the "capitalist West". Later studies have shown that the overall Soviet technological level was not at all as high as that in the West, with a few notable exceptions, notably in the aerospace industry (Amann & Cooper, 1986; Hanson & Pavitt, 1987). In the post-Cold War era, the levels of Russian and East-European technology appear to have approached Western levels to a certain extent, but perhaps not as much as one would have expected. The literature makes clear that the former Soviet Union and Eastern Europe successfully *adopted* a wide range of advanced technologies, but that they have remained far behind the "West" in terms of developing their own *innovative capabilities*. East Asia—starting with Japan and continuing with the four "Tiger economies" (South Korea, Taiwan, Hong Kong, and Singapore) and ultimately China—has been far more successful in "catching up" with the West in this respect (Freeman, 1987; 1994; Sigurdson, 2006). For example, a comparative study of patenting activities in Eastern Europe and China showed that as of 2006 there were no signs of convergence between Eastern Europe's low levels and the much higher Western patenting levels, whereas Chinese patenting activities have been growing exponentially since the mid-1990s (Högselius & Long, 2006). There are some interesting variations on this theme, however. Russia, for example, has been portrayed as a country of great engineering minds that in no way always operate in an imitative fashion or at "low technological level". On the contrary, Russian inventors and engineers have for centuries been at the forefront in developing numerous technologies, from locomotives to light bulbs. The problem is that Russia's innovative new technologies often fail to diffuse (Graham, 2013). Högselius (2005) has further argued that as far as innovative dynamism is concerned, whether in past or present, it is usually more rewarding to study the forces at work behind the "success stories" that do occur, such as the unusually creative spirit that characterized the Estonian ICT industry from the mid-1990s.

Generally speaking, there are obvious difficulties in trying to objectively determine the overall technological level of a given country or region and relate it to that of other regions. When analyzing the pre-industrial era, during which Western and Eastern technologies were not competing with each other, it is probably impossible. Apart from the fact that no country or region has ever assumed leadership in each and every technological field, there is a clear degree of subjectivity in specifying the factors that supposedly make one technology "more advanced" than another. The very notion of more/less "advanced" technology is inherently problematic, as it presupposes that technological "levels" can be

measured on a simple, one-dimensional scale. Several historians of Chinese science and technology, notably Francesca Bray and Nathan Sivin, have objected strongly to what Bray refers to as "the essentially negative 'Needham question'," that is, "why did China fail to develop capitalism, industrialization and the scientific revolution?" Their argument is that historians of science and technology need to move away from such teleological perspectives and accept that pre-industrial China and other Asian societies did not necessarily have any ambition to develop industrial capitalism. Asia's engineers were guided by other goals, and their degree of success needs to be evaluated in terms of how well these were attained—not in terms of their success in imitating the West. The challenge for the historian of Ancient Chinese technology, they stress, is not to explain the failure to westernize, but to explain the remarkable stability and unity of Imperial China. In particular, this concerns China's ability to feed an extremely large population (Bray, 1986; 1998).

This discussion relates directly to the notion of technological "styles". It is clear that Ancient China and other eastern civilizations differed from pre-modern Europe and Russia in important respects, not least in terms of which technological areas were prioritized. In the case of agricultural technology, for example, much of East Asia's efforts were devoted to enabling and perfecting rice farming, which was virtually non-existent in Europe. Similarly, Asian hydraulic engineering was more oriented toward irrigation systems than European hydraulic engineering. Some of these regional peculiarities are closely related to differences in climate and other characteristics of the natural environment in the respective regions. But there are also differences between East and West that derive from culture and society rather than from nature. During the Cold War, for example, the Soviet Union prioritized the development of military technology to a much greater extent than either Europe or Japan. The Sputnik triumph was one important result of this. At the same time, the Soviets paid scarce attention to the development of, for example, consumer goods. The Soviet bloc was also notoriously weak in some areas that their governments did not wish to support for political reasons. Long-distance telephony, for example, was identified as a potentially counterrevolutionary tool in the Soviet Union and was thus not supported. In contrast, radio and TV broadcasting were well developed, since the use of these communication technologies could much more easily be controlled by the government, while also constituting powerful propaganda instruments (Campbell, 1995).

Another dimension of technological styles refers to the ways of organizing the innovative process. The Great Divergence was very much about the West finding new organizational and institutional forms to stimulate technological change. As early forms of capitalism strengthened in Europe, the ways in which the innovative process was organized came to differ more and more both from Russia and, in particular, the Far East (Hanson & Pavitt, 1987).

During the Cold War, the Soviet Union set out to challenge Western capitalist ways of organizing technological development. Moscow's ideologists and social theorists argued that the mainly private and decentralized character of capitalist technological organization must lead to a massive waste of resources. For example, an electricity transmission line in the West, the Soviets reasoned, often could not be built along a straight line, because private landowners could refuse to allow it to pass through their domains. As a result the line had to follow a technically and economically irrational course. Only through centralized, state-led planning, the communists argued, could the most efficient route be used. They pointed to competition between private companies for market dominance as an equally irresponsible waste of resources. Sometimes tens or hundreds or even thousands of private companies invested separately in trying to develop and master one and the same new technology. The communists thought it more rational to centralize the innovation process through cooperation and a centrally planned division of labor (Hanson & Pavitt, 1987).

There were many actors in the West during the Cold War who feared that this thinking was correct. Yet the Soviet attempts to make reality of their ideas proved unexpectedly troublesome, and in most cases their efforts failed to yield desired results. The capitalist West, in spite of its arguably irrational technological style, turned out to be technologically superior in nearly all areas. Recently, however, there have been a number of studies pointing to the fact that Western technological development has not been as decentralized or privately dominated as previously thought. For example, companies have cooperated with each other much more extensively than what many analysts would have expected, given market-economy conditions, and government funding and control of the innovative process has played an enormously important role, not least in the United States (see, e.g., Nelson, 1993). Conversely, a recent study of the "Soviet Internet" has shown that Soviet innovative activities in data communications were characterized by "unregulated competition among self-interested institutions, bureaucrats, and others"; in other words, "the socialists behaved like capitalists" (Peters, 2017). All in all, capitalist and communist

technological styles perhaps did not differ as much from each other, after all, as has earlier been argued.

During the 1980s another fear emerged in the West: that the Japanese technological style was more conducive than Western ones to rapid technological progress. Japanese industry was rapidly catching up with the West, and soon even began overtaking the West in some areas. This generated much self-criticism in the West, particularly in the United States. Japan was seen to have organized the innovation process in an ingenious way, with powerful conglomerates of industrial companies, research institutes, banks, and so on, interacting in a highly efficient way. Versions of this approach were seen to prevail in South Korea and elsewhere (Freeman, 1987). Today this debate is popping up again in the West's nervous observations of China's technological rise.

6.   Infrastructural integration

We now come to the third and last set of studies in the history of East–West technological interaction. It focuses on large technical systems and their role in materially connecting Eastern and Western territories with each other.

Railways, in particular, come to the forefront here, forming by far the most popular objects in East–West infrastructural integration. Railway historians have mapped how the emerging Western European railway network at an early stage linked up with that of Russia (by 1862 it was already possible to travel from Western Europe to St. Petersburg, via Warsaw), how it expanded into the Ottoman Empire, and how Russia's imperial railway system penetrated into Caucasia, Central Asia, Siberia, and the Far East.

The most ambitious and famous project in this category is clearly the Trans-Siberian Railway, which in its original version was a transnational rather than a national project. Although controlled by Russia, it involved far-reaching system-building in and transit through China. Moreover, since the Russian railway network was already integrated with the Western European one, the Trans-Siberian also became a route of great importance to Western European travelers to the Far East.[8] Other railroad projects of Eurasian significance that have attracted

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[8]   For the history of the building of the Trans-Siberian Railway, see in particular Marks, 1991. For the history of the Baikal-Amur Mainline (BAM) Railway, constructed in the late Soviet period, see Ward, 2009.

scholarly attention include Russia's railways into Turkestan, which were of crucial military and colonial significance and were closely linked to the geopolitical struggle between Russia and Britain for control over Central Asia,[9] and the famous Baghdad Railway—the "Berlin-Baghdad Express," as Sean McMeekin calls it—which historians have identified as a decisive component in Germany's colonial ambitions and empire-building (McMeekin, 2010; McMurray, 2001). There have also been several fascinating studies of the attempts to link up some of the Western colonial territories in China—notably Shanghai, Qingdao, and Hong Kong—with China proper, and of the competition between Russian, Chinese, and Japanese "railway imperialisms" in Manchuria (see in particular Elleman & Kotkin, 2010, and (in Chinese) Wang, 2010).

A basic challenge for East–West railway historians has been to identify the actors that made such projects possible, what their motives were, and how they were able to cope with and overcome obstacles with regard to everything from daunting geographical barriers such as mountains and deserts to cultural and political divides. These questions have constituted the point of departure for studies of other infrastructural sectors as well. In the railway case, the diversity of actors has been found to involve private companies and national railway administrations, but also transnational bodies such as the League of Nations and the *Verein Deutscher Eisenbahn-Verwaltungen* (Association of German Railway Administrations, which, despite its name, extended far beyond the German lands and was of considerable importance for integrating Western and Eastern European networks).[10] Other key themes have included the competition between rival "system builders"—to use the Hughesian concept—and between alternative routes, along with studies of the dynamics of technical standardization, especially of the railway gauge, with the main Russian gauge ending up being larger than the Western European and Chinese standards. The thesis that military planning led Russia to opt for a different standard remains subject to debate, but as military historians have shown Russia's different standards—apart from the gauge this also concerned signaling technology, water supply, train weights, and the like—were one of the factors that turned Hitler's assault on the Soviet Union during the Second World War into a nightmare for the Nazis (Stahel, 2009, pp. 136, 248, 332–333; Van Creveld, 2004, pp. 155–174; Kaiser & Schot, 2014, Chapters 4–5).

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[9]   For railways in Central Asia and in the Russo-British "Great Game," see Hopkirk, 1990, pp. 430–446 and Sergeev, 2013, in particular pp. 154, 290.

[10] The role of the League of Nations in the planning of railways during the interwar period is dealt with in depth in Anastasiadou, 2012. The role of the Verein is analyzed in depth by Schot *et al.*, 2011 and Kaiser & Schot, 2014, Chapter 4.

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Another intriguing dimension of East–West railway historiography is the multitude of visions and projects that never materialized. The French engineer Ferdinand de Lesseps, for example, generated a vivid debate in the late nineteenth century by proposing that Russia's Central Asian railways be extended into Afghanistan and British India. Some observers regarded such connections, especially if combined with a railway tunnel under the English Channel, as the most promising way of establishing overland transport links between the British Isles and the Empire's jewel in the East. In the end de Lesseps failed to mobilize support for this idea (Högselius *et al.*, 2016, pp. 30–31). A variation on the Indian railway theme is the Italian diplomat Carlo Enrico Barduzzi's interwar proposal to establish overland connections not only to India, but all the way to Saigon in French Indochina—a "Trans-Asiatic Railway." This project was framed as an alternative to the Trans-Siberian, which had come under Bolshevik control, and it was to follow a route that did not include Russia. Indeed, its main purpose would be to prevent the spread of Bolshevik propaganda in non-Russian Asia and to consolidate Western dominance in the Far East. Barduzzi tried to convince the League of Nations and the Italian government of the project's importance and feasibility, albeit in vain. Yet the idea of a non-Russian "Iron Silk Road"—a railway between Europe and the Far East—remained on the agenda throughout the Cold War era. Following the rise of China as an economic superpower the vision is currently more alive than ever (Anastasiadou & Tympas, 2014).

East–West waterways constitute another intriguing infrastructural theme. The most important—and well-studied—is clearly the Suez Canal (completed in 1869), in whose construction de Lesseps played a central part.[11] Regular East–West sea routes also depended on supporting infrastructure in the form of way stations at places such as the Cape of Good Hope (Ward, 2009). Moreover, in Europe there were far-reaching visions of waterway construction in the form of canals across the interior of the Eurasian continent. Some were exceptionally ambitious. In the midst of the Cold War, for example, Czechoslovakia's hydraulic engineers fancied a pan-European network of canals extending from the Rhine to Moscow and, as imagined by Jan Smetana, the director of Prague's Water Research Management Institute, onward across the Urals to the Pacific (Janáč, 2012, p. 182). The Soviets, however, were more focused on developing what they called the "Northern Sea Route," which extended from Murmansk to Vladivostok and depended heavily on powerful icebreakers for its materialization (Josephson, 2014).

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[11] For the history of the Suez Canal's construction, see Zarabell, 2003; Marlowe, 1964; and Kinross, 1968.

During the interwar era, aviation emerged as an additional transport infrastructure spanning much of Eurasia. In 1932, the Soviet Union set up Aeroflot, which developed air services covering nearly all corners of the communist empire, from Leningrad to Vladivostok. Western Europe's imperial powers set out to create links to their colonies, with Britain and the Netherlands competing fiercely in establishing air services to the Far East. By the 1930s both KLM and Britain's Imperial Airways offered regular flights from Western Europe all the way to Australia. Air France opened a route to French Indochina (Högselius *et al.*, 2016).

Following the advent of Western Europe's first electrical telegraph lines in the 1840s, it did not take long before European system-builders set about creating similar communication links with Russia and Asia. Russia emerged as an important transit country for telegraph connections to India and the Far East. The first British-Indian connection, for example, which went online in 1865, involved transit through Tsarist territories. A trans-Siberian telegraph line was also built. In this case British interests cooperated both with Russia and with a Danish telegraph company, the Great Northern. The Danes managed to attain an unexpected key role in linking up England with the Far East by way of the Baltic Sea and Siberia. At one point it even seemed that Russian cables, extended across Bering's Strait, would become the preferred telegraph route to the Americas. This radical idea became obsolete through the success of submarine telegraph cables across the Atlantic in 1866. Yet the trans-Siberian lines retained their importance for telegraphic communications between Europe and the Far East. This was because they proved technically more reliable than the British-controlled submarine links that were soon built to Asia (Headrick, 1991, pp. 20–24; Hugill, 1999, pp. 36–39; Jacobsen, 2009).

After the Second World War, the East–West transport and communications infrastructure was complemented by sophisticated infrastructure for the transmission of oil, gas, and electricity between Europe, Russia, and Asia. Oil pipelines were built from the heart of the Russian oil industry in the Volga-Urals region both to the west and the east. The western pipeline network, which took the form of a cooperative venture involving not only the Soviet Union itself, but also communist Poland, East Germany, Czechoslovakia, and Hungary, had three branches, the terminals of which were at Ventspils in Soviet Latvia, Schwedt in East Germany, and Bratislava in Czechoslovakia. The system thus did not cross the "Iron Curtain" separating the "capitalist West" from the "communist East" in Cold War Europe. Yet, it was of considerable importance for the West as

well, since the system made access to Soviet oil cheaper and easier for Western European oil importers (Högselius *et al.*, 2016).

In eastern directions, the pipeline system extended from the Volga oil fields to Irkutsk on Lake Baikal, just north of Mongolia. In the mid-1960s, the Soviet Union initiated negotiations with Japan about extending this pipeline all the way to the Pacific. The Chinese government, however, protested vehemently against this proposal, interpreting the pipeline as a military object. Seeking to prevent the emergence of a Soviet-Japanese energy alliance, the Chinese government even initiated its own oil exports to Japan, which subsequently grew to become a factor of considerable strategic importance in the Far East. Whether or not it was due to this Sino-Japanese oil trade, the extension of the Soviet pipeline from Irkutsk to the Pacific never materialized (Woodard, 1980).

After the collapse of the Soviet Union, China also developed far-reaching energy cooperation with Kazakhstan, and, to a somewhat lesser extent, the other ex-Soviet Central Asian republics. As one consequence the Kazakhstan–China Oil Pipeline, completed in 2009, saw the light of day. Originating in western Kazakhstan, near the formal geographical border between Europe and Asia, it constitutes an important new infrastructural connection between East and West (see, e.g., Erickson & Collins, 2010). Although it is probably too early for historians to study such recent links in a serious way, the completion of analogous projects in the past points to an opportunity for historians of technology to engage in the public debate by putting ongoing infrastructural developments in perspective.

From the late 1960s, the Soviet Union, in addition to its role as a key oil exporter, emerged as an important supplier of natural gas to Europe. Governments and gas companies in Western Europe and the Soviet Union agreed to build a pipeline system which, in contrast to the oil pipeline infrastructure, transcended the Iron Curtain. Austria became the first Western country to import Soviet natural gas in this way, starting in 1968. By the mid-1970s, Germany, Italy, Finland, and France had also been connected. A number of communist East European countries linked up with the system as well, which was further expanded over the course of the next couple of decades. From the 1990s, Turkey was integrated into the supply of Russian natural gas. The integration of natural gas networks between Europe and the Middle East, for its part, remained weak. A scheme to export large volumes of piped Iranian natural gas to Western Europe by transit through the Soviet Union was contracted in 1975, but failed to materialize following the 1979 Iranian Revolution (Högselius, 2013). Only recently have

new attempts been made to interconnect the Middle East with Europe in natural gas, the main focus being on a pipeline through Turkey.[12]

Starting in the 1960s, the Soviet Gas Ministry also built pipelines from gas fields in Uzbekistan and Turkmenistan eastward into Kazakhstan and westward through the Central Asian desert toward the Urals and later on to the European part of Russia. By the time the Soviet Union was dissolved, Turkmenistan had become an important supplier of natural gas to Eastern and Western Europe as well (by way of transit through Russia and Ukraine) (Högselius, 2013). Shortly afterward the post-Soviet Central Asian republics initiated negotiations with China about gas deliveries. In 2009, the first Central Asia–China Gas Pipeline was inaugurated, enabling supplies from Turkmen fields all the way to the Chinese East Coast—essentially following the old Silk Road. In this way, Turkmenistan uniquely emerged as a supplier of natural gas to both Europe and China (Erickson & Collins, 2010). In 2014, a further agreement was concluded between Russia and China, paving the way for construction of a gas pipeline from Russia to China. In this way, Russia, like Turkmenistan, seems to be on its way to becoming a large-scale exporter of natural gas to both Europe and China.

Electricity systems added to the networked East–West geography of technology. East and West European actors in the interwar era took inspiration from the internationalist spirit of the pan-European movement and the League of Nations in identifying transboundary electricity systems as tools well-suited for boosting international solidarity and securing peace. A number of grand visions were formulated, featuring proposals for transmission grids that would stretch from the British Isles or the North Sea coast to Russia's interior. The enthusiasm quickly dwindled, however, following the onset of the Great Depression and a new wave of economic nationalism in the 1930s. The prospects for financing a top-down multinational power pool plummeted (Lagendijk & Van der Vleuten, 2013). During the Second World War, Hitler's engineers sought to reanimate the idea of an East–West electricity grid—under Nazi control—but failed to realize more than a handful of relatively minor projects (Lagendijk, 2008, p. 117).

In the postwar era, the two superpowers opposed the creation of East–West electricity links in Europe. Nature-based synergies across the Iron Curtain were thus not to be exploited; economics and efficiency were to be sacrificed for the sake of political, military, and ideological considerations. As a result, the East–

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12   The main artery of this project is the Trans-Anatolian Pipeline, which according to current plans will mainly transport gas originating in Caspian gas fields. It remains to be seen whether gas from countries such as Iran and Iraq can also make use of the new connection.

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West divide in electricity was clearly visible—in sharp contrast to what was the case in oil and natural gas. Only a few East–West electrical connections were built.[13] East of the Iron Curtain, however, the making of an interconnected Soviet electricity grid in itself constituted a massive East–West system-building effort. In the 1970s, the Soviets started developing ultra-high-voltage power lines, through which cross-border integration within the communist bloc increased. Such international connections included not only links between the Soviet Union and the countries of Eastern Europe, but also comprised the integration of Mongolia into the Soviet grid starting in 1978. From then on, electrical generators and machines operated in parallel over a vast area stretching from Berlin to Ulan Bator (Lagendijk, 2008; Tchalakov *et al.*, 2013; Högselius, 2006). The grid might have been further extended into China, had the Sino-Soviet ideological conflict not prevented such initiatives.

7. Final discussion

This article has sketched three major research foci regarding the problem of East–West relations in the history of technology. An underlying argument has been that while the three forms of interaction have largely been studied in isolation from each other and by different groups of scholars, they would profit from being viewed as a single whole. This is so not least because they are interdependent. For example, improvements in the East–West transport and communications infrastructure during the past two centuries have made it much easier and cheaper for Eastern and Western nations to acquire technologies from each other—through processes of technology transfer—and to follow new technological trends on the "other side". Moreover, large East–West infrastructural projects have often paved the way for technology transfer themselves. The Trans-Siberian Railway, for example, brought Western and Russian railway technology to China's northeast, while oil and gas pipeline construction between the Soviet Union and Western Europe rested on the principle that the West pay for the gas through transfers of steel pipe, compressor stations, and other advanced technology to the Soviet bloc.

An intriguing question in this context is whether the intensification of East–West interaction in terms of new infrastructure projects and technology transfer,

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[13] For the history of these exceptions that prove the rule, see Michelsen, 2013; Tchalakov et al., 2013; Tympas et al., 2013, and, for the case of Austria's connections with its Eastern neighbors, Lagendijk, 2008. An interesting case is also the surprisingly slow postwar disconnection of the electricity links existing between East and West Germany.

as observed since the mid-nineteenth century, has stimulated a convergence of technological levels and styles. From a theoretical point of view, it is not obvious that more intense interaction leads to convergence. This is because technological styles typically form within the framework of national and regional technological systems (or "systems of innovation," to use a modern term) and such systems do not necessarily respond in a convergent way to pushes and pulls from "alien" systems. To understand this, one may connect to the argument in social systems theory that a system is capable of reacting to change only in accordance with its own logic, rationality, and history. Depending on the structural configurations and the often long-established traditions of carrying out certain activities in a system, different systems are likely to deal with new problems in very different ways (Luhmann, 1989, pp. 15ff). This is consistent with Bertrand Gille's argument that, for example, the so-called "leading" or "the latest" technology cannot be introduced into a system unless a certain degree of coherence prevails between the technologies already existing in that system (Gille, 1986, p. 404). It is an empirical question, however, as to whether technological levels and styles are influenced in any significant way by technology transfer and large infrastructural projects. Such studies would clearly add valuable components to our knowledge about how different forms of East–West interaction influence each other.

Another avenue for further research would be to study the three dimensions of East–West relations sketched here over a longer period of time, so as to better discern major long-term continuities and path-dependencies in the patterns of interaction. This would be of interest not least in relation to the radical developments going on in our own era. Current social science analyses of Russian and East-Asian science and technology, for example, would clearly benefit from a greater awareness of the historical experience regarding East–West technological relations.

Acknowledgements

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