Technology Transfer and Early Industrial Development: Evidence From the Sino-Soviet Alliance

Michela Giorcelli Bo Li*

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This paper studies the long-term effects of technology and know-how transfers on structural transformations. In the 1950s, the Soviet Union supported the construction of the 156 Projects, which were large-scale, capital-intensive industrial clusters in China. These projects included a technology transfer, consisting of state-of-the-art Soviet machinery and equipment, and a know-how transfer, via the training of Chinese engineers, production supervisors, and high-skilled technicians by Soviet experts. We use newly assembled data that follow steel plants for over four decades, and we exploit natural variation in the transfers they eventually received. We find that, while production advantages stemming from Soviet technology faded away if not complemented with training, the know-how transfer had a long-lasting impact on plant performance, stimulated technology upgrade when China was a closed economy, and increased exports to the Western world when China engaged in international trade. The know-how transfer also generated productivity and technology spillovers onto complementary establishments.

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[*] Contact information: Michela Giorcelli, University of California, Los Angeles, NBER, CEPR, CESifo, IZA, and J-PAL, 9262 Bunche Hall, 315 Portola Plaza, Los Angeles CA, 90095, USA. Email: mgiorcelli@econ.ucla.edu; Bo Li: Guanghua School of Management, Peking University, Email: boli@gsm.pku.edu.cn. Cyrus Hou Yeung Ho, Yujing Huang, Leon Wang, Boxiao Zhang, and Jade Tianhong Zhang provided excellent research assistance. We thank Ran Abramitzky, David Atkin, Nick Bloom, Bruno Caprettini, Laura Cohen, Dora Costa, Michele Di Maio (discussant), Alvaro Garcia, Rick Hornbeck (discussant), Jiandong Ju, Naomi Lamoreaux, Nicholas Li, Ernest Liu, Kalina Manova (discussant), Nathan Nunn, Dimitris Papanikolau, Fernando Parro, Luigi Pascali, Nancy Qian, Martin Rotemberg, Dimitrije Ruzic (discussant), Vincenzo Scrutinio, Xuan Tian, John Van Reneen, Eric Verhoogen, Shang-Jin Wei, Guo Xu, and Ting Xu (discussant), as well as Elira Kuka, Jared Rubin, and Danila Serra through the Adopt-a-Paper program. We also thank seminar and conference participants at Harvard, Stanford, Yale, Berkeley Haas, UCLA, LSE, UBC, Michigan, George Washington, Tucson, Auburn, Wilfrid Lauriel, Oxford, LUISS, Bologna, Padova, Melbourne, Tsinghua, Chicago Fed, the NBER Summer Institute, the NBER Productivity Lunch, the Cliometrics Conference, the Second Women in International Economics Conference, the AFA, the CEPR/LEAP Workshop in Development Economics, the Barcelona GSE Summer Forum, the Pacific Conference for Development Economics, the Webinar Series in Finance and Development, the LSE Asia Economic History Seminar, the Online Economic History Workshop, and the Ridge Conference for helpful comments and discussion. We are also thankful to senior officials at Statistics China for declassifying the historical data for this research and to historians at the National Archives Administration of China for their help in accessing archival materials. Li thanks the National Natural Science Foundation of China (Project No. 72342020) for financial support.

1 Introduction

Industrialization is a key driver of economic development. As economic activity has moved from the agricultural sector to the more-productive industrial sector, states have grown rich (Gollin et al., 2013; Herrendorf and Schoellman, 2015; Porzio et al., 2021). Several developing countries have attempted to accelerate this process with "Big Push" development strategies. Such strategies involve building a modern industrial sector through massive and simultaneous public investments in capital-intensive industries (Rosenstein-Rodan, 1943; Murphy et al., 1989; Allen, 2011), frequently supported by technology and know-how transfers from the most advanced economies (Hoekman et al., 2004; Robinson, 2009; Stokey, 2021).

Despite the widespread use of industrial policy in the 20th century, empirical evidence on its causal and long-run implications remains limited. This is mostly due to a lack of natural variation in its delivery, as policymakers decide which firms and industries to target. Moreover, while the effects of such policies took several years to materialize, systematic data following the targeted units over time are rarely available. It is also challenging to disentangle the impact of technology transfer from the role of know-how diffusion, as they generally occur simultaneously (Chandra, 2006; Mostafa and Klepper, 2018).

This paper studies the long-term effects of technology and know-how transfers on structural transformations, using evidence from the Sino-Soviet Alliance. In the 1950s, to help China industrialize, the Soviet Union supported the construction of the "156 Projects," large-scale, capital-intensive industrial clusters in heavy industries—an investment equal to 45% of Chinese GDP in 1949. Considered the most comprehensive technology transfer in modern industrial history and a vital factor in Chinese economic development, the 156 Projects entailed a technology transfer, consisting of state-of-the-art Soviet machinery and equipment, and a know-how transfer, via the training of Chinese engineers, production supervisors, and high-skilled technicians by Soviet experts (Lardy, 1995).

In building a comprehensive new dataset, collected and digitized from several historical archives, we have combined information on the 156 Projects with annual reports on plant performance in the steel industry. These documents provide granular data on output quantity and quality, production processes and workforce between 1949 and 2000, which we complement with records of plant technological upgrades. For all the other industries, we collected data on firm-level outcomes when available, in 1985 and between 1998 and 2013.

Our identification strategy relies on the fact that the implementation of the 156 Projects encountered significant delays. As a consequence, when in 1960 the Sino-Soviet Split caused the sudden interruption of Soviet aid, some plants had already received both Soviet physical capital and Soviet know-how, others had gotten only Soviet physical capital, and the remainder eventually got no Soviet transfers. In our empirical analysis, we compare the outcomes of these three groups of plants over 40 years. These plants had statistically indistinguishable baseline characteristics, faced similar economic incentives, were not systematically allocated different inputs or production quotas by the government, and were located in comparable geographical areas. Furthermore, they were on statistically indistinguishable performance trends before receiving the Soviet transfers.

Our core results show that while the production advantages stemming from Soviet technology faded away when not complemented by Soviet training, the know-how transfers had a long-lasting impact that widened over time. The steel industry plants that received Soviet physical capital had a differential performance increase relative to plants that received no Soviet transfers in the six years after the intervention. Then, the effects started to decay and were no longer significant after 20 years. By contrast, production and productivity of plants that also received the know-how transfer rose by around 20% within 20 years of Soviet intervention relative to that of plants that got only physical capital, and continued to grow, reaching a cumulative effect of roughly 50% after 40 years. These findings are not driven by political connections, or exposure to concurrent historical events, such as the Great Leap Forward or the Cultural Revolution.

We next show that the complementarities between Soviet capital and know-how stimulated quality and technology upgrades, which contribute to explain the persistent results we observe. In the 1960s and 1970s, when China's interaction with foreign countries was extremely limited, only plants that also received the know-how transfer increased production of high-quality steel, developed new steel-making processes, and adopted modern machinery, which ultimately replaced Soviet capital when it became obsolete. Once China began gradually opening to international trade, in 1978, such plants relied dramatically less on Western physical capital, imported more foreign equipment complementary to their machinery, and exported systematically more high-quality steel than plants that received only Soviet physical capital. These results are consistent with their performance improving even more after 1978. Conversely, we find no difference between plants that received only Soviet physical capital and plants that got no Soviet transfer on these upgrading and trade measures.

A major implication of the Big Push theory is that large investments in heavy industries can become self-sustaining due to spillover effects across industries (Kline and Moretti, 2014). Did the 156 Projects generate such effects? We find that only establishments with backward and forward linkages with plants that received Soviet know-how exhibited higher productivity, more technological upgrades when China was a closed economy, and more exports when China opened to international trade. These results confirm the importance of human capital spillovers in fostering increased productivity and local economic development (Glaeser et al., 1992; Moretti, 2004).

The contribution of this paper is threefold. First, our paper relates to the literature on technology transfer and diffusion in developing countries (see Verhoogen, 2023 for a comprehensive review). Given the low quality of domestic innovations, firms in less-developed economies may find it profitable to adopt technologies from the most advanced ones instead of developing their own (Caselli and Coleman, 2001; Comin and Hobijn, 2010; de Souza, 2022). Consistently, several papers have shown the positive impact of foreign technologies embedded in capital goods on firm performance (Pavcnik, 2002; Mel et al., 2008; Goldberg et al., 2010; Bloom et al., 2013; Bruhn et al., 2018; Giorcelli, 2019; Hardy and Jamie, 2021), while others have documented the existence of substantial barriers to their adoption (Atkin et al., 2017; Bloom et al., 2020; Juhasz et al., 2024). Our paper shows that the impact of technologically advanced capital goods does not persist if it is not accompanied by proper engineering know-how. In doing so, our work also contributes to research on the role of engineers in economic development. Considered a key link between scientific insights and practical application during the First Industrial Revolution (Mokyr, 2005; Yuchtman, 2017; Hanlon, 2022), engineers became even more important during the Second Industrial Revolution when the increasing global knowledge needed to be adapted locally (Squicciarini and Voigtlaender, 2015; Maloney and Caicedo, 2022; Juhasz et al., 2024). Focusing on more recent times, Romer (1990)'s model of endogenous growth puts "research engineers" at the center of the growth process, while Murphy et al. (1991) show that countries with a higher share of engineers grow faster than those with more lawyers. Our paper highlights that engineers are not only complementary to physical capital in the early stages of industrialization, but also prevent investments in new technologies from becoming obsolete by promoting technological upgrades. This channel can generate long-run local development even in a closed, command-economy, as China was until the early 1980s.

Second, our paper adds to the literature on the Big Push and industrial policies. Building on the seminal contributions of Rosenstein-Rodan (1943) and Murphy et al. (1989), a growing body of research has documented that large public investments in strategic industries of little-industrialized countries have positive, persistent effects on local development, manufacturing employment, targeted sectors, downstream users, and individual long-term outcomes (Wade, 1990; Carlin et al., 2013; Kline and Moretti, 2014; Liu, 2019; Hanlon, 2020; Choi and Levchenko, 2021; Kim et al., 2021; Bianchi and Giorcelli, 2023; Lane, 2023; Mitrunen, 2025). To the best of our knowledge, this paper is the first to use granular, nonexperimental data to disentangle the effects of technology and know-how transfers of Big Push industrial policies, tracking industrial clusters from their foundation to recent years. Our focus on the Big Push toward industrialization of China, the country that experienced "the fastest sustained expansion by a major economy in history" (Morrison, 2019), speaks to the debate about the role of the state in achieving economic development (Evans, 1992; Besley and Persson, 2010; Dell et al., 2018). Our results echo Carlin et al. (2013), who show how command economies that were preindustrial when planning was imposed benefited more, in terms of long-run GDP per capita, from physical and human capital investments than they were harmed by the economic costs of weak market incentives.

Third, our paper is related to the literature on spillover effects. Existing research has focused on spillovers determined by foreign direct investments, the opening of large plants (Javorcik, 2004; Javorcik et al., 2008; Greenstone et al., 2010; Alfaro-Urena et al., 2022), worker mobility (Stoyanov and Zubanov, 2012), managerial-knowledge diffusion (Bloom et al., 2013; Bianchi and Giorcelli, 2022), and sectoral industrial policies (Liu, 2019; Fan and Zou, 2021). Our setting allows us to disentangle the spillover effects of technology transfer from spillovers that follow know-how diffusion. In terms of context, a closely related paper to ours is Heblich et al. (2022), which compares counties that hosted the 156 Projects with similar counties that did not, showing negative long-run spillovers on production due to overspecialization. By contrast, our paper focuses on the short-, medium-, and long-run direct effects of the 156 Projects, juxtaposing plants built under the Sino-Soviet Alliance that received or did not receive the Soviet transfers, and documenting productivity spillovers and technology upgrade stemming from engineering knowledge diffusion.

The rest of this paper is organized as follows. Section 2 describes the Sino-Soviet Alliance. Section 3 introduces the data. Section 4 presents the empirical framework and discusses the identification strategy. Section 5 studies the effects of the technology and know-how transfers on plant outcomes. Section 6 examines firm upgrading, while Section 7 focuses on the spillover effects. Section 8 concludes.

2 The Sino-Soviet Alliance and the 156 Projects

2.1 The Big Push Towards the Industrialization of China

After the People's Republic of China (PRC) was established in 1949, one of the newly formed government's major goals was to build a modern industrial system. Lacking the expertise to do so independently, PRC officials sought collaboration from the Soviet Union (Ji, 2019). Since the 1930s, the latter had followed a Big Push development strategy. Industrialization was pursued through centrally planned and coordinated investments in heavy industry and interlinked sectors (Allen, 2003; Cheremukhin et al., 2017). To replicate this model in China, on February 14, 1950, the two countries signed the "Sino-Soviet Treaty of Friendship, Alliance, and Mutual Assistance," which established, in addition to military assistance, widespread economic cooperation.

The Big Push toward Chinese industrialization was promoted through the construction of large-scale, capital-intensive industrial clusters in heavy industries, known as the "156 Projects" (Zhang et al., 2006). These projects aimed to replicate whole Soviet factories and encompassed a comprehensive transfer of technology and know-how from the Soviet Union. Central to the First Five-Year Plan (1953–1957), their total value amounted to $80 billion (in 2020 figures; $20.2 billion in 1955 RMB), equivalent to 45.7% of Chinese and 6.5% of Soviet GDP in 1949 (Lardy, 1995; Zhang et al., 2006).[1]

The importance of the 156 Projects in Chinese economic history can hardly be overstated. Defined as "a major turning point in the course of China's modernization" (He and Zhou, 2015), these projects are considered the "largest technology transfer in human history" (Cehn and Zofka, 2022), "unprecedented in scale and scope," even relative to the U.S. Marshall Plan (Bayasgalan, 2022), and a vital factor in Chinese industrialization and economic development (Lardy, 1995; Zhang et al., 2006; Zhang, 2015).

While the 156 Projects were by far the largest foreign-development plan undertaken by the Soviet Union, they were part of a broader, global strategy implemented during the Cold War to limit U.S. influence (Guan-Fu, 1983). Between the 1950s and 1980s, the Soviet Union offered technology transfers to several Communist countries, including Vietnam, Laos, Cambodia, North Korea, Cuba, and other states, for instance India, Egypt, Ghana, and Turkey.[2] Notably, the Soviet intervention promoted similar Big Push industrialization strategies in all

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[1] The Soviet Union did not provide any aid in the form of grants; it lent China only $2.9 billion ($300 million in 1955 dollars) in response to a Chinese request for 10 times that amount. This loan was to be used to "repay the Soviet Union's delivery of machinery and equipment [...]" (Lardy, 1995). The prices of such items were calculated according to world market prices.

[2] Soviet technology transfer to India was an essential part of the Indian Third Five-Year Plan (1961–1966). It provided design services, production equipment, technical guidance, and personnel training for 102 projects in the public sector, 80 of which were eventually implemented (Engerman, 2018). Since 1966, the Indo-Soviet cooperation was expanded to incorporate military supply. For instance, the Soviet Union transferred technology to co-produce the Mikoyan-Gurevich MiG-21 jet fighter, earlier denied to China.

these countries, by supporting the construction of large, publicly owned factories in heavy industries.

2.2 The 156 Projects

The implementation of the 156 Projects was undertaken through several agreements signed by China and the Soviet Union between 1952 and 1957. Each project involved the construction of multiple plants—duplicates of Soviet establishments—and was supposed to receive both technology and know-how transfers from the Soviet Union. The technology transfer consisted of state-of-the-art Soviet physical capital, such as machinery, equipment, and blueprints, that "would enable China to have its own complete production line of an industrial sector, rather than become dependent on of the Soviet-centered industrial system" (Hirata, 2018, p. 170). Through this transfer, China received the best-available Soviet physical capital and transitioned from having industrial technology that was a century behind that of developed nations in 1949 to a comparable level in just ten years (Naughton, 2007).

The know-how transfer included in-plant technical and industrial training by Soviet experts to the engineers and production supervisors, as well as instruction for high-skilled Chinese technicians on how to operate the new machinery. The engineer training was comprehensive: classes in math, physics, and chemistry, along with lectures on organizational, technological, and planning methods. Supervisor training, based on "scientific management" principles, included classes on operational planning, statistical and quality-control methods, and worker management (Clark, 1973).[3]

The Soviet experts were expected to spend on average three years in Chinese plants, sharing technical data as well as engineering and product designs, helping to survey geological conditions, selecting plant sites, and directing plant construction (Zhang et al., 2006).[4] Still today, Soviet knowledge transfer is thought to have "accelerat[ed] the progress of science and laid the foundation for modern technology in China" (News, 2009).

The locations of the 156 Projects were chosen based on proximity to natural resources, potential to transform underdeveloped areas, and protection from military attacks (Bo, 1991; Zhang et al., 2006). Consequently, they were concentrated in the northeastern (Heilongjiang, Jilin, Liaoning) and inner regions (Shaanxi, Shanxi, Gansu, and Hubei; Figure 1). In this respect, the 156 Projects reshaped the geographical distribution of Chinese industrialization, since the majority of firms built before the 1950s were located in the coastal areas (Lardy, 1995; Zhang et al., 2006).

Only 10 projects were located on the sites of preexisting enterprises, built during the Japanese occupation of Manchuria (1932–1945). For these projects, Soviet assistance could

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[3] For instance, Soviet experts introduced quality-control methods to reduce scrapped output. They also organized duty management, having the outgoing shift thoroughly inspect the machines and hand them over to the next shift in good condition, so production could start immediately (Wu and Yi, 2022). Notably, "scientific management" principles were adopted by Soviet planners in the early 1930s from the United States (Clark, 1973).

[4] Despite numerous references to Soviet technical personnel in the Chinese press, no reliable totals are available on the number of Soviet military and civilian specialists assigned to Communist China. According to the statistics recorded by the Soviet Ministry of Foreign Affairs, 5,092 Soviet technical personnel were working in China between 1952 and 1959.

rely to some extent on preexisting buildings, which, however, were deeply transformed or reconstructed based on Soviet-provided technical designs and where whole new sets of more modern Soviet machinery and equipment were installed (Weiyuanhui, 1991; Hirata, 2018).

These changes were necessary for two reasons. First, while Japanese-built enterprises received capital goods and technology transfers from Japan in the 1930s, their production largely focused on low-quality goods—such as pig iron to be transformed into steel in mainland Japan—which in turn generated limited backward linkages within the region, in stark contrast with the goals of the Sino-Soviet Alliance (Lardy, 1995; Hirata, 2018). Second, in the months after the end of WWII, the Soviet army implemented a "de-industrialization" of Manchuria, removing machinery from Japanese-built plants and sending it to the Soviet Union. As a result, Manchuria's industrial production fell dramatically: by 1946, in the steel industry, productive capacity dropped between 50% and 100%, and in the coal industry, between 80% and 90% (Pauley, 1946).[5] Before the start of Soviet aid, Chinese leaders agreed to employ Japanese engineers who had remained in Manchuria, also to provide technical training to young Chinese staff members. However, this collaboration was short-lived: as soon as the Sino-Soviet assistance ramped up, Japanese engineers were replaced by Soviet experts, and they were prohibited from operating the newer Soviet machinery for fear that they would spy for Japan or the United States (King, 2015). Most of the Japanese engineers were repatriated by 1953 (Hirata, 2018).

Soviet Aid in the Steel Industry. Chinese leaders, in particular Chairman Mao Zedong, believed that Chinese industrial development should strongly rely on steel production. Not surprisingly, the steel industry accounted for 45% of the total investment in the 156 Projects and led to the construction of 20 clusters. Each cluster was in turn composed of several steel plants, 304 in total. Notably, while all the plants within an industrial cluster were formally under a unique company, they operated as different firms, each with its own planning, financial, and labor departments (Weiyuanhui, 1991).

Soviet technology in the steel and iron industry was considered among the best in the world (Clark, 1995; Gangchalianke, 2002). For instance, during the 1950s the Soviet Union built and operated the world's best blast furnaces—these were installed in Chinese plants in Anshan, Wuhan, and Baotou, even before being employed in some Soviet factories (Lardy, 1995; Dong and Wu, 2004). The advancement of Soviet technology was recognized in the United States, as well. After studying the Soviet and Chinese industries for decades, Clark (1995) argued that Soviet steel technology transferred to China was comparable to that of the most developed Western economies. The Soviet effort in promoting Chinese management impressed India's Prime Minister Nehru as well. While visiting the Anshan plant, he compared the Soviet transfer in China with the British and U.S. ones in India, concluding that in China, "the entire process of production in the plant [was] being operated by Chinese experts," while in India the British and Americans "never allow[ed] Indians to manage the most important mechanism of the plants" (Dong and Wu, 2004; Hirata, 2018).

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[5] While China was entitled to receive key equipment as war reparations from Japan, a considerable amount of it was damaged during disassembly, shipment, and the Communist-Nationalist Civil War, or relocated to Taiwan along with the retreating Nationalist forces (Xu, 2019).

2.3 Delays in the 156 Projects and the Sino-Soviet Split

Despite the rosy picture of "Great Friendship" promulgated by the Soviet and Chinese authorities, the 156 Projects suffered severe difficulties on the ground, with the consequence that machinery, equipment, and experts almost always arrived later than planned.

In fact, the large volume of machinery and equipment requested by China had to be produced on an ad hoc basis by Soviet enterprises, which often lacked the capacity to fulfill the demand (Zhang et al., 2006). Given China's high need for steel at the time, the Soviet and Chinese governments decided to temporarily install old, domestic Chinese capital in all the newly built plants with the idea of replacing it with state-of-the-art Soviet machinery as soon as it was delivered (State Economic Commission, 1958, 1959; Ji, 2019). However, the pressure to produce beyond capacity caused several accidents on the Soviet side. Multiple factory fires, floods, and railway accidents destroyed critical equipment produced for China, causing severe delays in its delivery (Borisov and Koloskov, 1980). Moreover, Soviet experts, few in number to begin with, had to learn how to operate the machinery (scarcely employed, even within the Soviet Union) before traveling to China, and they relied on translators, who often needed more time than expected to learn Chinese (Filatov, 1975; Hirata, 2018).

In light of these delays, it would have been profitable for China to prioritize the most promising projects, but the country faced many challenges in doing so. First, it was too dependent on aid from the Soviet Union, which often did not even respond to the complaints of the PRC Ministry of Foreign Affairs (Zhang et al., 2006). Moreover, the fact that Chinese plants aimed at replicating specific Soviet ones made it impractical to reallocate machinery or equipment across the 156 Projects (Filatov, 1975). And unfortunately, the Soviet experts who did arrive in China had just learned how to operate specific machinery, and their translators had been trained in project-specific terminology, which strongly limited the possibility of reallocation across different projects (Borisov and Koloskov, 1980).

Further complicating matters, the Sino-Soviet Alliance descended into turmoil in the late 1950s over political and ideological disputes. Despite attempting to maintain a bilateral relationship in the early 1960s, the two countries couldn't reach an agreement; the formal end of their cooperation in 1963 became known as the Sino-Soviet Split. Long before that, the 156 Projects had already been dramatically reduced in scope and number. In July 1960, the Soviet Union suddenly withdrew its experts from China and stopped providing machinery and equipment.

These practical and political matters strongly affected the completion of the 156 Projects. By the time of the Split, some plants had already received both Soviet physical capital and know-how, other plants had received only Soviet physical capital, and the remainder got no Soviet transfers and continued to operate with Chinese domestic capital. In fact, China still lacked the resources and human capital to replicate the Soviet plants and capital goods autonomously, and Soviet experts took all the relevant materials with them (Lardy, 1995; Zhang et al., 2006). Moreover, China faced an embargo from the Western world until at least 1978, which forced the country to rely almost exclusively on its own resources for about 20 years after the Split.[6]

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[6] Notably, after the Sino-Soviet Split, Albania, in ideological and political disagreement with the Soviet Union, became the sole foreign partner of China (Mehilli, 2017). To foster this alliance, under the

Notably, the final differences across plants had little to do with the initial design of the projects. For instance, the Bautou, Tangshan, and Taiyuan Projects were each supposed to have a plant duplicating the Red October (Krasny Oktyabr) blast furnace plant in Volgograd. As soon as it became clear that the completion of the three furnaces would have taken longer than planned, Chinese experts decided to install old electric furnaces—left unused in other factories in the coastal area of Qingdao—to start plant operations (Weiyuanhui, 1994). Soon after the blast furnaces for Bautou and Tangshan were shipped in 1957, a fire decimated the one destined for Taiyuan. The Soviet Union ensured that it would reproduce it as soon as its plant operations could resume, but due to the Split this never happened (Filatov, 1975). The fact that blast furnaces were brand new, even in the Soviet Union, implied that Soviet experts themselves had to learn how to operate them first before leaving for China. The team, also delayed because its translators couldn't learn Chinese fast enough, eventually arrived in China in 1958, but could visit and train Chinese workers only in Bautou; due to the Split, they were forced to return to the Soviet Union before heading to Tangshan (Filatov, 1980).

As a result, despite being initially designed to be identical, the three plants ultimately were very different, as described by Clark during his visit to China in the early 1960s. The Bautou Blast Furnace Plant emerged as "an impressive modern, giant metallurgical complex, where the entire process of production in the plant employ[ed] systematic quality control methods, resulting in high-quality steel" (Clark, 1973, p. 11). The Tangshan Blast Furnace Plant appeared as "a surprising state-of-the-art massive steel facility [...] whose workers were copying Soviet designs and products without thinking. As a consequence, the resulting products had many flaws and the scrapped output was enormous" (Clark, 1973, p.12). Finally, the Taiyuan Plant was "of an impressive size for the eyes from a distance and apparently brand-new, but, as one walk[ed] in, production capital [was] a mixture of that of a Japanese and a Soviet factory of the 1930s, as the factory was employing the domestic capital, never replaced by Soviet furnaces" (Clark, 1973, p. 12).

2.4 State-Owned Enterprise Incentives in a Command Economy

From 1949 until at least the early 1980s, China operated as a command economy.[7] All industrial factories were state-owned and production decisions were centrally planned. The government controlled the economy by setting output targets, allocating inputs, and fixing goods prices (Perkins, 2014). As explained by Kornai (1992), command economies are "resourced-constrained," as opposed to the "demand-constrained" market economies: firms continue to produce until they fulfill planned quotas or exhaust available inputs. Under this

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Sino-Albanian Friendship Society (1959–1978), China offered economic, military, and political assistance, as well as food and in-kind subsidies, though doing so was often beyond its productive and financial possibilities. Overall, the cooperation was not very successful, strongly limited by geographical distance and profound historical and cultural differences, and often resulted in an enormous waste of resources (Biberaj, 1986). When China started resuming its interactions with the United States, the diplomatic relationship with Albania rapidly deteriorated, leading to the Sino-Albanian Split in 1978.

[7] In this section, as well as in other parts of the paper, we use terms such as "profits," "prices," "performance indicators," and "firm autonomy." These terms refer to the specific institutional context of a command economy and do not imply the existence of market-driven incentives or profit-maximization in the neoclassical sense.

system, Chinese state-owned enterprises (SOEs hereafter) were largely not incentivized to transform inputs into outputs efficiently. Their main objective was to maximize output to meet production targets, rather than to pursue profits, most of which were remitted to the state (Hirata, 2018). As in most command economies, this incentive structure often led to the overproduction of low-quality goods and widespread inefficiencies.

During the 1950s, the Chinese government attempted to mitigate the low-quality issue and introduced non-quantity performance indicators, for instance profits, output quality, and cost reduction (Perkins, 2014).[8] In the early 1960s, following the newly established principle of "quality first," it was further decided that products that failed to pass quality checks were not allowed to leave the factories and downstream firms were entitled to reject faulty products (Communist Party of China, 1961).[9] Nevertheless, despite these repeated policy efforts, low product quality persisted as a structural problem during these three decades (Perkins, 2014; Hirata, 2018).

While managerial incentives were primarily directed toward maximizing output, meeting non-quantity targets also provided some economic benefits. In fact, upon their completion, SOEs could retain a portion of their profits and use those funds to pay bonuses and invest in improvements to their enterprise (Walden, 1989; Richman, 1969).[10] While the official Chinese government narrative may not provide an accurate characterization of the reality on the ground, field evidence indicates that Chinese plants did pursue a combination of non-quantity indicators – usually two to five – even though output quantity remained the most important metric (Richman, 1969). In the 1960s and 1970s, SOEs could retain a further share of profits for the renewal of key equipment, implementation of technical upgrades, and adoption of new technologies (Weiyuanhui, 1991; Perkins, 2014). By contrast, major investment projects that would have substantially expanded plant production capacity were decided at the centralized level (Perkins, 2014). Undoubtedly, until 1983 managers' ability and incentives to maximize profits remained limited and the share of profit retention low. For the 304 plants at the core of our analysis, it ranged between 6.7 to 15.8% between 1952 and 1983, while for the other steel plants between 2.5 and 7.8% (Table A.1, columns 1 and 2). However, as the only source of independently controlled funds for SOEs, it was probably not completely insignificant and played an important role in financing technological upgrading

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[8] More specifically, 11 performance indicators in addition to output of major product were introduced as soon as 1952: gross value of output, profits, cost reduction, trial production of new products, cost-reduction quota, total number of employees, total employees at year's end, total wage bill, average wage, labor productivity, and key technical-economic norms (raw materials consumption, level of mechanization, and rate of equipment utilization, Perkins, 1968). Starting in 1957, the compulsory indicators were output quantity, profits, total number of employees, and total wage bill (State Council, 1957). Starting in 1962, there were seven total performance indicators: output quantity, output quality, total wage bill, profits, cost reduction, capital turnover, and introduction of new products (Yang, 2022). Such indicators remained in place even during the Cultural Revolution (1966–1976) to guarantee continuity with the earlier period and to not disrupt heavy industry production.

[9] Notably, the goal of pursuing quality production, although less salient than in early 1960s, was not totally abandoned even during the Cultural Revolution, and in 1975 firms were ordered to "put output quality, variety and standards as their first priority" (Communist Party of China, 1975).

[10] Granik (1990) explains that bonuses, including managers' bonuses, were drawn exclusively from firms' profit retention. Therefore, "to the degree that top managers of Chinese enterprises attempt to maximize their own personal bonuses, they can do this best by maximizing the total bonus pot in their enterprise" (Granik, 1990, p. 166).

and modernization.

Chinese capability to impose strict planning remained weaker than in other planned economies, in particular the Soviet Union (Wong, 1986). This, in turn, gave plants relatively more autonomy and flexibility in decision making. In terms of inputs, plant managers could, to various extents, influence the material allocation quotas. Moreover, given that plants often received more or fewer inputs than needed due to inaccurate planning, extra-plan exchanges between enterprises were tolerated and, occasionally, explicitly allowed, albeit on a limited scale (Perkins, 2014). For the 304 plants, the share of inputs that could be independently purchased ranged between 15.3% and 25.8% between 1952 and 1983, compared with 5.8% to 8.9% in other steel plants (Table A.1, columns 4 and 5). To reduce the issue of production of goods with no demand, the Chinese State Department helped firms establish point-to-point contacts upstream and downstream, allowing them to discuss detailed input specifications and quality directly (State Economic Commission, 1963). In terms of output, managers could negotiate production targets with their superiors and had some discretion in determining the product mix, 5 to 30% of which could be sold independently (Richman, 1969). This discretion was, however, less pronounced in industries that produced homogenous goods, such as steel, where independent sales primarily involved by-products (Richman, 1969; Wong, 1986; Perkins, 2014; Hirata, 2018). For the 304 plants, the share of independently sold output ranged between 6.8% and 15.7%, compared with 2.5% to 7.2% for other steel plants (Table A.1, columns 7 and 8).[11]

It is important, however, not to overstate the scope of this autonomy. SOEs were ultimately subordinated to an administrative hierarchy and were obligated to fulfill the government's production targets. Therefore, their ability to influence key performance indicators, such as output and productivity, remained limited.

This scenario radically changed after 1978, when China began gradually opening to international trade and undertook a series of reforms that gave plants more autonomy. Notably, since 1983 SOEs were entitled to keep a large portion, if not all, of their after-tax profits. Moreover, the Chinese government introduced the so-called "dual-track" pricing system: firms, including SOEs, were allowed to buy and sell at market prices once they had fulfilled their plan responsibilities, which created incentives for their managers to expand market-oriented activities (Naughton, 2007).

3 Data

In this section, we describe the data we collected and digitized from several historical archives. Additional details can be found in Appendix B.

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[11] Albeit independent input purchasing and output selling remained limited, Hirata (2018) explains that Angang had to purchase more than 20% of the raw materials it needed through the market and that the PRC government remained far from having total control of its output products during the First Five-Year Plan.

3.1 The 156 Projects

We retrieved the list of the 156 Projects built under the Sino-Soviet Alliance by accessing the official agreements signed by the Soviet Union and the PRC between 1950 and 1957, available at the National Archives Administration of China. While the initial discussions aimed at 156 civilian projects, the final number was 139. For each project, we collected information on name, location, industry, total investments, capacity, number of workers, and name and number of plants. For each plant, we retrieved reports compiled during the program completion that indicate whether and when plants received Soviet physical capital and equipment or the visits of Soviet experts.

The 156 Projects predominantly focused on heavy industries: 23.0% were in electricity, 21.6% in machinery, 20.1% in coal, and 14.4% in steel (Figure A.1, Panel A). Only two projects (1.4%) were in light industries. In terms of expenditures, the steel sector alone accounted for 45.1% of total investments (Figure A.1, Panel B).

The average project was planned to start in 1955 and last 5.6 years, while the expected arrival of Soviet physical capital and experts spanned between 1954 and 1963. The 156 Projects were massive, with average investments of $580.3 million (in 2020 values), 8.7 plants, and 39,910 employees (Table 1, Panel A, column 1).[12]

The 20 steel projects were larger in terms of investments ($746.9 million), number of plants (15.2), and number of workers (46,670) than those in other industries, confirming their vital importance in the First Five-Year Plan (Table 1, Panel B, column 1). They were composed of 304 steel plants, which in turn aimed at duplicating 14 different Soviet plants. When the Split suddenly interrupted the program, 98 steel plants had received both physical capital and know-how transfers (32.2%), 91 had received only the physical capital transfer (29.9%), and 115 received no Soviet transfers (37.8%).

3.2 Plant-Level Data in the Steel Industry

We manually collected and digitized restricted, plant-level annual reports that the Steel Association compiled every year from 1949 to 2000 for all the plants operating in the steel industry. The reports contain rich information on plant performance, such as quantity and quality of steel products, inputs usage, specific machinery and technologies in use, and the number and types of workers (unskilled workers, high-skilled workers, and engineers). Using the plant name, location, county, and province, we manually and uniquely matched the 304 plants built in the 20 steel industrial clusters to their performance data.

A natural question is whether plant performance data, at the core of our analysis, are accurate. In fact, until at least the early 1980s, China was a command economy, which creates potential conceptual and measurement shortcomings in its officially released statistics. First, variation in the quality and methods used to compile official statistics, as well as the high decentralization of the statistical institutes, undermines their internal validity (Koch-Weser, 2013). Second, as in most authoritarian regimes, systematic misreporting or data falsification may have occurred, especially in periods of economic instability or to hide government

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[12] Total employment in the 156 Projects amounted to 5.5 million workers—only 3% of China's total workforce, but almost 40% of the country's employment in the industrial sector in 1952.

policy failures (Koch-Weser, 2013). Third, plant managers themselves, rewarded for firm performance, may have had incentives to show better-than-actual outcomes, for instance to meet the production goals set by the central government (Lardy, 1995).

While we cannot say for sure that the Steel Association reports were exempt from these issues, four points should be considered while using this data. First, the Steel Association reports were primarily intended for internal government use and therefore required accurate evaluation of plant performance. For this reason, these reports were highly monitored and verified by industry peers, significantly reducing the manipulation margins.[13] Moreover, the officially released aggregate production data was compiled by Statistics China, a separate, independent source. Manipulations were more likely to occur in the aggregate data rather than in the Steel Association reports. Second, the fact that the 304 plants were usually exceeding the government-set production quotas and could purchase inputs and sell their own products reduced the incentives for over-reporting. Third, the Steel Association reports contain the quantities of steel production, usually difficult to manipulate since their products were delivered to downstream state-owned firms, which could cross-check the information. Fourth, while assessing the direction of data manipulation ex-ante is challenging, after the Sino-Soviet Split, the Chinese government wanted to tie up loose ends with the Soviet Union as quickly as possible.[14] Therefore, in this specific setting it is reasonable to think that, if any manipulation occurred, it should have aimed at underestimating rather than overestimating the impact of the Soviet intervention, especially in the long run. This would work against us finding results.[15]

Moreover, to have a more objective measure of the production processes in the 304 plants, we complement the production data with information on subsequent technology adoption at the plant level, which we collected from the Chinese Ministry of Commerce and the Ministry of Industry and Information Technology historical archives. This data not only come from a different source but also provide a more direct measure of the plant technological upgrades, one that is less subject to measurement issues. Specifically, these data show whether firms adopted new technology or production techniques or whether they developed new products or processes. We also collected information on China's adoption of foreign technology (which began after China opened to international trade) by digitizing the contracts signed with technologically advanced countries, such as the United States, Japan, and some in Western Europe, between 1978 and 2000. These contracts contain detailed descriptions of the type of imported technology (machinery, equipment, licensing, and consulting) and their use within Chinese plants.

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[13] The substantially higher reliability of the internal reports relative to the official statistics has been acknowledged by several Chinese economic historians (Zeitz, 2011; Wu and Yi, 2022).

[14] For instance, China rushed to repay its debts to the Soviet Union immediately, even though it could have done so over ten years (Zhang et al., 2006).

[15] For instance, during the Great Leap Forward, the Chinese government wanted to show the efficacy of labor-intensive methods of industrialization, which would emphasize manpower rather than machines and capital expenditure, in stark contrast with the goals of the Soviet intervention (Clark, 1973; Lardy, 1995).

3.3 Firm-Level Data in All Industries

We manually collected and digitized confidential, firm-level data from the Second Industrial Survey, conducted by Statistics China in 1985 and declassified for this project. It covers the 7,592 largest firms in 1985, spanning across 40 industries and provides key performance data, such as output, sales, profits, fixed assets, and employees. Using name, location, and province, we manually and uniquely matched the 139 projects to their 1985 performance.

Finally, we manually matched the 139 industrial firms with their 1998–2013 performance from the China Industrial Plants database. This database, compiled yearly from 1998 to 2013, covers more than 1 million public and private industrial firms above a designated size in China.[16] It includes a rich set of information on firms: firm output, number of employees, and profits, as well as ownership structure and capital investment.

4 Identification Strategy

Our identification strategy relies on delays in the implementation of the 156 Projects combined with the Sino-Soviet Split. In 1960, when the Soviet Union suddenly interrupted the program, all 304 steel plants had been built and had begun operating with Chinese capital. As noted earlier, some had already received *both* Soviet physical capital and know-how, others had received *only* Soviet physical capital, and the remainder had received *no* Soviet transfers at all.

We estimate the effects of the Soviet technology and know-how transfers via the equation:

$$\text{outcome}_{it} = \alpha_i + \theta_t + \sum_{\tau=-5}^{40} \beta_\tau (\text{Physical Capital}_i \cdot \text{Years after Transfer}{=}\tau_{it}) \qquad (1)$$
$$+ \sum_{\tau=-5}^{40} \gamma_\tau (\text{Know-How}_i \cdot \text{Years after Transfer}{=}\tau_{it}) + \epsilon_{it}$$

where outcome_{it} is logged tons of steel and productivity (TFPQ) of Chinese plant i in year t;[17] $\text{Physical Capital}_i$ is an indicator for plants that received Soviet physical capital transfer; Know-How_i is an indicator for plants that also received Soviet know-how transfer;[18] $\text{Years after Transfer} = \tau_{it}$ is an indicator when a calendar year is τ years before or after the year in which plant i received or was supposed to receive the Soviet transfer. The excluded year is $\tau = -1$. Plant fixed effects α_i control for variation in outcomes across firms constant over time. Year fixed effects θ_t control for nonlinear variation in outcomes over time. ϵ_{it} is

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[16] The data include firms with more than 5 million yuan assets before 2011, and 20 million yuan after 2011.

[17] Specifically, we compute total factor productivity quantity (TFPQ) as the residuals of an OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects. Details about productivity estimation can be found in Appendix C2. Table C.3 shows that our productivity results are robust to different methods of estimating TFP.

[18] We code the Know-How indicator equal to one also for nine plants that were receiving Soviet transfers when the Split occurred. This choice is motivated by the fact that, though Soviet experts were suddenly withdrawn by the Soviet Union in July 1960, they had already delivered between 32 and 35 months of training relative to a planned duration of 36 months. We provide sensitivity checks of this definition in Appendix C.1.

the error term. Standard errors are block-bootstrapped at the industrial-cluster level with 1,000 replications to control for potential autocorrelation within clusters. As all plants were still alive and state-owned in 2000, Equation 1 estimates an intensive margin effect.

Under the identifying assumption that the performance of the 304 plants would have been on the same trend in the absence of Soviet transfers, the coefficient β_τ captures the effect of Soviet physical capital on plant performance, relative to plants that received no Soviet transfer τ years after receiving it; the coefficient γ_τ captures the additional effect of Soviet know-how on top of physical capital τ years after receiving it. While the identification assumption cannot be tested directly, in the rest of this section we discuss several pieces of evidence that corroborate our empirical strategy.

4.1 Are the Outcomes Comparable for the 304 Plants?

Before formally testing our identification assumption, we investigate whether the 304 plants' outcomes are comparable, given the command-economy context in which they operated until at least the early 1980s.

We first analyze whether the 304 plants faced the same incentives. In Section 2.4, we discussed that Chinese SOEs worked to maximize output primarily. However, they also had some incentives to pursue a combination of non-quantity performance indicators. We therefore check whether the 304 plants maximized the same set of such indicators over the years, focusing on the five (profits, product quality, cost reduction, total wage bill, and development of new products and projects) chosen by more than 90% of the plants between 1952 and 1983. Output is always reported as a key performance indicator by all firms, so we don't include it in this analysis. Regressing a dummy for pursuing each of these five indicators on the Physical Capital and Know-How regressors interacted with year dummies does not indicate systematic differences between plants that received or did not receive transfers (Figure 3, Panels A–E). Fulfilling these five indicators allowed SOEs to retain a share of their profits, which they used to pay bonuses, finance their own investment decisions, and fund technology upgrades until 1983. While the exact share of profit retention could change across plants and over time, it was not statistically different across the three types of plants (Figure 3, Panel F).

Second, we test whether the level of managers' autonomy was comparable across the 304 plants. While their decision-making remained limited, plant managers had some influence on material allocation and production targets, and could buy and sell a portion of inputs and outputs. However, the 304 plants were not systematically different in terms of their input share—defined as the ratio between inputs allocated to a plant and the total amount of planned output—or quotas they were allocated, nor in the share of inputs they could buy and outputs they could sell independently (Figure A.2, Panels A–D). It is worth noting that, probably due to their size and importance for Chinese steel production, the 304 steel plants could retain a higher share of profits and had greater discretion in inputs and outputs purchases than other Chinese steel plants (A.1). Finally, the government neither allocated a differential amount of transfers or loans to the 304 plants nor differentially improved their geographical accessibility, for instance thanks to the construction of roads and railroads (Figure A.2, Panels E–F).

While their proximity to natural resources meant they had direct access to raw materials, the 304 plants could rely on more than 2,200 suppliers, created to guarantee a stable supply (State Economic Commission, 1963). According to firm reports, this system of suppliers was successful in stabilizing production and reducing input backlogs (He, 1958; Ji, 2019). Consequently, the 304 plants were little exposed to the cyclical input shortages that characterize command-economy enterprises. In terms of personnel, given China's dearth of technological and managerial expertise, their engineers and managers were less exposed to rotation from the Chinese Communist Party (CCP), especially after the First Five-Year Plan. Unskilled workers were recruited at the local level through the labor bureaus (Bian, 1994).

This evidence shows that on average the 304 plants faced the same incentives and operated under the same economic conditions and production constraints. Therefore, we conclude that standard firm outcomes, albeit different from market economies, could be reasonable indicators of the 304 plants' performance within the Chinese context.

4.2 Tests for Pre-Trends

The key identification assumption for our empirical strategy requires that the 304 plants were on the same performance trend in the five years before receiving the Soviet transfer, when they were all operating with Chinese domestic capital. To test if it was the case, we estimate the set of pre-Soviet intervention coefficients from Equation 1, which are small in magnitude and never statistically different from zero (Figure 2). Moreover, some are positive and some are negative, confirming a lack of any pattern. Finally, the p-value of the F-statistics at the bottom of each panel indicate that we can never reject the null hypothesis that the interaction terms are jointly equal to zero. Notably, in both tables plant capital stock does not show any trend across the 304 plants, further confirming how similar they were before receiving the Soviet transfers.

These findings suggest that the 304 plants were following a statistically indistinguishable performance trend in the five years before receiving the Soviet transfer.

4.3 Balancing Tests at the Plant-Level

The historical evidence discussed in Section 2.3 suggests that receiving or not receiving the Soviet transfers before the Split depended on delays on the Soviet side and was not related to the initial design of the projects. If this was the case, the 304 plants should have on average similar baseline characteristics.

To systematically test this hypothesis, we first show that the expected value of Soviet capital, its expected delivery year or the expected year of Soviet experts arrival were substantially the same across the 304 plants. Moreover, the few plants built on the site of pre-existing Japanese factories were not more likely to receive the Soviet transfers, for instance in an attempt to exploit prior expertise or infrastructure (Table 2, Panel A, columns 1-3). Finally, plants that received the Soviet transfers were not located closer to natural resources, such as coal or coke deposits, a circumstance that could have allowed them to prosper in the long run due to natural advantages, rather than the Soviet intervention (Table 2, Panel A, columns 1-3).[19] In all these cases, we fail to reject the null hypothesis of equality across their means (Table 2, Panel A, columns 4-6). These tests are important for our identification, as they corroborate the historical evidence that the transfers plants eventually received did not depend on the original features of the program, their importance for Chinese industrialization or their potential success.

Next, we document that the mean values of quantity and quality of steel production, and productivity appear very similar across the three groups of plants in the year before they were supposed to receive the Soviet transfers (Table 2, Panel B, columns 1–3). Notably, all these variables exhibit a small variance. The fact that the 304 plants operated with the same Chinese domestic capital while waiting for the Soviet transfers likely leveled off differences in blueprints and specifications used to build them. Moreover, the number of employees and their composition are comparable across the 304 plants. For all these variables, we fail to reject the null hypothesis of equality across their means (Table 2, Panels B and C, columns 4-6). We conclude that the 304 plants were statistically equivalent in terms of their outcomes the year before the Soviet intervention, which further confirms our pre-trend tests.

4.4 Balancing Tests at the Cluster- and County-Level

The 304 plants were not located in industrial clusters or counties with systematically different characteristics, which may have affected their outcomes in addition to the Soviet transfers. First, cluster characteristics do not predict the probability of receiving the Soviet transfers. None of the coefficients estimated by regressing the indicators for receiving Soviet physical capital and know-how on cluster characteristics is statistically significant, and we always fail to reject the null hypothesis of joint equality of the coefficients to zero (Table A.3, columns 1–3). Second, regressing these two variables on county characteristics in 1953 estimates small and non-statistically-significant coefficients (Table A.4, columns 1–3).

4.5 Resources Reallocation Across the 304 Steel Plants

A potential threat to our identification strategy may arise if the Chinese government reallocated physical capital and experts from plants that received the Soviet transfers to plants that did not. Before the Split, even in light of the delays faced by the program, it would have been very challenging for the Chinese government to redirect Soviet transfers to the most promising plants, as discussed in Section 2.3. In fact, the 304 plants aimed at replicating specific Soviet ones, making it impractical to reassign machinery, equipment, or experts. This is fully consistent with the evidence presented in Section 4.3, which shows that the 304 plants had very similar baseline characteristics.

To generate spillover effects after the Split, the Chinese government may have decided to reallocate Soviet machinery, equipment, and Soviet-trained workers from plants that received the Soviet transfers to plants that did not. However, it would have been highly unprofitable

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[19] We also show that the 304 plants' average distance from national and provincial borders, the coast, and Treaty Ports (open to trade with the Western world beginning in the mid-19th century and where most economic activities were concentrated), and from infrastructures such as highways and railroads was not statistically different plants that received or did not receive the Soviet transfers (Table A.2, Panel B, columns 1–3).

to remove brand-new furnaces from already productive plants, especially in light of the high demand for steel and the costs of moving capital across the country (Zeitz, 2011; Ji, 2019). Moreover, Soviet-trained engineers and technicians, essential for their own plants' operations, were in limited number, which strongly reduced the possibility of reallocation across different enterprises.[20] Beyond these considerations, it is worth noting that a similar scenario would downward-bias our results.[21]

Another possibility is that the Chinese government may have decided to disproportionately channel its investments to plants that received the Soviet transfers, allowing them to prosper even more in the long run. While this is certainly a possibility, after the Split Chinese leaders wanted to show that the country could industrialize even without the advanced Soviet technology (Lardy 1995; Zhang et al. 2006; Zhang 2015). We already discussed that plants that received the Soviet transfers did not get differential input or quotas allocation or loans and transfers from the central government. We will also show that they were not differential exposed to major historical events, such as the Great Leap Forward or the Cultural Revolution (Table A.10).

5 Effects of Physical Capital and Know-How Transfers

In this section, we estimate the effects of physical capital and know-how transfers on the performance of the 304 steel plants. We next rule out potential alternative explanations for our findings and assess the role of other major historical events. Finally, we extend our analysis to all of the 156 Projects in 1985 and between 1998 and 2013.

5.1 Production and Productivity of Steel Plants

We start our analysis by investigating if production quantity, the most important performance metric for SOEs, differentially changed among the 304 plants upon receiving the Soviet transfers. The results of estimating equation 1 indicate that output, measured in tons of steel, produced by plants that received Soviet physical capital was not significantly higher than that of plants that received no Soviet transfers for the first two years after receiving the state-of-the-art machinery, probably due to the difficulties in operating them without proper training. It then started differentially growing, reaching an 12.0% higher

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[20] A notable exception is represented by Angang which promoted technology transfer within China by sending its skilled workers to newly-built plants in other regions (Hirata, 2018). While we were not able to track the movements of all the workers, we did not find evidence of workers' transfer from Angang to our comparison plants.

[21] Another potential channel of spillovers from plants that received the Soviet transfers to plants that did not could be generated by CCP politicians' rotations. For instance, focusing on the last two decades, Lin et al. (2024) shows that bureaucrats, rotated across prefectures by the CCP, transferred industrial knowledge from the old to the new jurisdiction, and implemented favorable industrial policies. However, between 1949 and 1990, such rotations were less common than in later years. Out of 6,524 CCP bureaucrats who served in the 304 plants' prefectures during these years, only 73 (1.1%) were moved to other administrative areas. Notably, none of them was rotated from prefectures where plants that received the Soviet transfers were located to those where plants that received no transfers operated. We discuss political rotations in more detail in Section 5.2.

level seven years after the Soviet intervention. Then, the effects started slowly decreasing and were no longer significant after 20 years (Figure 4, Panel A and Table A.5, column 1).

Conversely, output of plants that also received the know-how transfer rose by 7.9% relative to that of plants that received only the physical capital transfer in a mere two years since the Soviet intervention and by 19.1% within 20 years. The gap between the two groups of plants continued to widen, with an estimated output increase of 48.7% 40 years after the program (Figure 4, Panel B, and Table A.5, column 1). Single-difference event studies indicate that our findings are largely driven by the increased performance of plants that received either one or both types of Soviet transfers, while output of plants that received no Soviet transfers remained mostly flat over time (Figure 4, Panel C).[22]

The dynamic of plant productivity (TFPQ) follows a similar pattern as output. TFPQ of plants that received a physical capital transfer rose up to six years after the Soviet transfer, with a 7.0% increase relative to plants that received no Soviet transfers, and was no longer significant after 20 years (Table A.5, column 2). TFPQ of plants that also received a know-how transfer increased between 7.6% two years after the Soviet transfer to 46.4% after 40 years, relative to plants that received only Soviet physical capital (Table A.5, column 2).

We further explore the increase in productivity by focusing on the different components of the production function. In addition to the aforementioned increase in output, we do not find statistically significant differences in number of workers and coke and iron quantities among the three types of plants (Table A.6, columns 1–3),[23] which suggests that the government did not allocate more or better inputs to plants that received the Soviet intervention. By contrast, capital stock, comparable across the 304 plants before the Soviet transfers, mechanically increased in plants that received the Soviet machinery in the intervention year, relative to plants that got no Soviet transfers, with the effects decaying over time, as such capital became obsolete. Capital stock remained comparable between plants that received Soviet machinery and plants that also received Soviet know-how up to ten years after the Soviet intervention, confirming that the latter were able to produce more output despite using comparable inputs (Table A.6, column 4).

These results are consistent with the output maximization goal SOEs pursued at least for the first twenty years after receiving the Soviet transfer. While their ability to influence performance remained limited during this period, SOEs which received the Soviet transfers used them to expand production as much as possible, which, in turn, drove the observed effects on productivity. Finally, an important caveat in interpreting our findings is that they are based on a comparison of physical quantities and avoid reliance on prices that were uniformly administered across firms in a given year. As such, they reflect performance under

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[22] Since firm exit was virtually nonexistent in China until the 1990s, one may wonder if the Chinese government artificially kept alive plants that received no Soviet transfer after the Split. To test for this possibility, we compare plants built under the Sino-Soviet Alliance but that got no Soviet transfer with other steel plants built in other industrial clusters after 1960. While this analysis has no causal interpretation, the former were larger and performed better than the latter, but there were no observable differences in the types of technology and production processes (Table A.8, columns 1–5).

[23] While the Chinese economy was a noncompetitive environment until at least the late 1980s and all plants in a given industry faced the same prices in a given year, any nonmarket clearing prices set by the government would be absorbed by year fixed effects in our regressions. This feature implies that we do not have any bias due to unobservable enterprise-specific variation in output or input prices.

shared institutional constraints rather than allocative efficiency.

Robustness Checks. Our findings are robust to a variety of modifications to the baseline specification. Specifically, our results remain very similar in magnitude if we control for fixed effects of the Soviet enterprise to be duplicated (Figures A.3 and A.4, Panels A and D) and industrial clusters (Figures A.3 and A.4, Panels B and E). While regressions with plant and year fixed effects are widely used in event studies, recent works document possible shortcomings of these two-way fixed-effects specifications (de Chaisemartin and D'Haultfoeuille, 2020; Goodman-Bacon, 2021; Borusyak et al., 2021). In particular, Sun and Abraham (2021) explain that, in the presence of heterogeneous treatment effects, the coefficients on the leads and lags of the treatment variable in an event study might place negative weights on the average treatment effects for certain groups and periods. To address this concern, we use an "interaction-weighted" (IW) estimator, as proposed by Sun and Abraham (2021), that confirms our main findings (Figures A.3 and A.4, Panels C and F).

In Section 4.1, we discussed that, in addition to output, more than 90% of the 304 plants maximized five key performance indicators (profits, product quality, cost reduction, total wage bill, development of new products and projects). While such indicators were not systematically different between plants that received or did not receive the Soviet transfers, restricting our sample to only plants that maximized the same set of indicators between 1952 and 1983 lead to results comparable or, if anything, larger than our baseline ones (Figures A.5 and A.6, Panels A and D).

Clustering at a different level of aggregation, such as at the plant, county, or prefecture level confirms the significance of our main specification (Figures A.7 and A.8). Finally, our results are robust to several alternative ways of estimating TFP (Table C.3).

5.2 Ruling Out Alternative Explanations

The Japanese Legacy in Manchuria. As discussed in Section 2.2, 30 steel plants were located on the sites of preexisting enterprises, built during the Japanese occupation of Manchuria and that received Japanese capital goods and technology transfers in the 1930s. While most Japanese machinery was removed after the end of WWII and these plants were not more likely to receive the Soviet transfers than newly built factories (Table 2), it could still be possible that the Soviet transfers interacted with the preexisting Japanese expertise.

To investigate this possibility, we repeat our main analysis excluding the entire region of Manchuria, which was also the largest recipient region of the 156 Projects investments. These estimates remain comparable with our baseline ones (Figures A.5 and A.6, Panels B and E). In addition, since some Japanese engineers remained in China until 1953 and were employed to restart heavy-industry production and for training purposes, we limit or sample to only plants earmarked to receive Soviet assistance after 1953 (by which time most of these engineers were forced to leave the country); we find results very similar to our baseline ones (Figures A.5 and A.6, Panels C and F). This is not surprising, since Japanese engineers, during their short stay after the start of the Sino-Soviet collaboration, were barred from operating the brand-new Soviet machinery due to fears of espionage (King, 2015).

We can conclude that the Japanese legacy in Manchuria and the location of heavy-industry clusters before the Sino-Soviet Alliance are not driving our findings.

Political connections and politicians' rotations. Plants that received Soviet transfers may have also been more politically connected than plants that received no transfers over time, or perhaps better politicians were allocated to their administrative areas, contributing to their economic success. To investigate this hypothesis, we collected data from the *People's Daily Online* database, which includes full biographies of both the secretaries of the Municipal Party Committee, directly linked with the central government, and the prefecture mayors, who represented the local government, from 1949 to 2018. Both secretaries and mayors were recruited by the CCP, and periodically rotated across prefectures to limit long-lasting interactions with local elites.[24] We use the database to reconstruct such rotations in the jurisdictions where the 304 plants were located.

Building on previous works of CCP recruitment (Jia et al., 2015; Francois et al., 2023; Wang and Yang, 2024), we test whether exposure to bureaucrats' rotations was different in the 304 plants' prefectures, under the assumption that lower political rotations may indicate stronger ties with plants' top management.[25] However, we do not find statistically significant differences in number of officials' rotations or length of their terms (Table A.9, columns 1,2, 5, and 6). Next, we proxy politicians' quality with years of education and years of experience in previous appointments, not finding statistically significant differences in these two measures across the 304 plants' prefectures (Table A.9, columns 3, 4, 7 and 8).

These results suggest that political connections and politicians' quality the 304 plants were exposed to remained comparable in the 40 years after the Soviet intervention.

5.3 Discussing Other Concurrent Historical Events

In China, the 1960s and 1970s were decades dense with historical events that, among other consequences, affected Chinese industrialization. In this section, we explore whether such events had a differential impact on the 304 plants.

Great Leap Forward (GLF). In 1958, the GLF, China's Second Five Year Plan, was launched to speed up industrialization, especially in the steel industry, and increase agricultural collectivization. During these years, the government put more emphasis on smaller-scale projects, and the use of backyard furnaces, only able to produce pig iron, was largely encouraged. Since the goal of the government was to demonstrate that economic development could be achieved by using domestic technology, the events related to the GLF should, if anything, downward-bias our results. Moreover, Clark (1995) explains how Soviet know-how allowed plant management to mitigate the pressure induced by the Great Leap Forward, thanks to the introduction of input-saving techniques to operate the blast furnaces.[26]

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[24] A tradition inherited from imperial China, bureaucrat rotations were implemented by the CCP since the founding of the PRC (The Economist, 2021). However, they became more salient in the 1990s, when the government embraced market-oriented reforms and started fighting corruption (Zeng, 2017). In Section 4.4, we note that we do not observe reallocation of politicians from prefectures with plants that received the Soviet transfers to prefectures with plants that received no transfers.

[25] Having officials serving in their home province was not common and should, if anything, weaken ties with plants' management, given Mao's aversion to practices that could have been perceived as favoring hometown or college "factions" (Fisman et al., 2020).

[26] To the best of our knowledge, none of the 304 plants were relocated to the countryside as a consequence of the GLF.

The GLF not only affected steel production but also caused a massive reallocation of workers from the agricultural sector to the industrial sector, which was not associated with a proportional increase in agricultural productivity. For this reason, the GLF is considered the primary cause of the Great Famine, which by 1961 had killed between 16.5 and 45 million people (Dikotter, 2010; Meng et al., 2015). While investigating the human costs of the GLF goes beyond the scope of this paper, such a big disruption in the workforce may have differently impacted the 304 plants. Using county-level cohort loss in 2000 as an estimate for the Great Famine severity, as in Chen and Yang (2019), we do not find evidence of differential exposure to the famine deaths in counties that hosted the 304 plants (Table A.10, column 1).

Third Front Movement. Starting in 1964, China undertook another massive industrialization campaign, the "Construction of the Third Front" (TF), which lasted for over a decade and built or moved large manufacturing plants to the South-Western and North-Western parts of the country, the so-called "Third Front Region." Fan and Zou (2021) document that the TF had long-run positive aggregate effects on the local economies, regardless of how developed the regions were when the campaign started. While the location of TF plants had minimal overlap with the 156 Projects[27] and none of the 304 plants were moved, TF investment may have differentially diverted resources from the 304 plants. However, counties with plants that received Soviet transfers did not receive more TF investments than counties with plants that received no Soviet transfers (Table A.10, column 2).

Cultural Revolution. Between 1966 and 1976, the Cultural Revolution, which aimed to purge any remnants of capitalism, led to the imprisonment of many high-skilled workers, as well as the closure of numerous schools and universities. While aggregate steel production declined during these years, the 304 plants were deemed too important for Chinese heavy-industry production and were left almost untouched (Esherick et al., 2006). The historical records that we accessed do not report any dismissal of managers or high-skilled workers from these plants during the Cultural Revolution. This finding is consistent with what Hirata (2018) described in detail for the Anshan Iron and Steel Company: the "Cultural Revolution's radical political campaigns were reconciled with the goals of industrial production, ensuring a continuity in the steel production."

We do not find evidence that any of these three historical events differentially affected steel plants that received or did not receive the Soviet transfers.

5.4 Effects across All Industries

We next test whether our results in the steel industry hold for firms in all industries in the medium and long run, using data on their performance in 1985 and between 1998 and 2013. We estimate the following specification:

$$\text{outcome}_{it} = \alpha + \beta \cdot \text{Physical Capital}_i + \gamma \cdot \text{Know-How}_i + \theta_{pst} + \nu_{it} \tag{2}$$

where outcome_{it} comprises value added, total factor productivity quantity (TFPQ),[28] and

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[27] Specifically, only 4.4% of the counties that hosted any of the 304 plants also hosted TF plants.

[28] To control for the higher heterogeneity of products when we include all the industries, relative to equation

workers of firm i in 1985 or in year t; Physical Capital$_i$ is an indicator for firms that received a physical capital transfer; Know-How$_i$ is an indicator for firms that received a know-how transfer; and θ_{cst} are county-sector-year fixed effects. For estimation in 1985, we don't have a time dimension, so province-sector-year fixed effects are replaced with province-sector fixed effects. Standard errors are clustered at the industrial-cluster level.

These estimates confirm our main results from the steel industry. In 1985 and between 1998 and 2013, value added, TFPQ, and employees of firms that received a physical capital transfer were not significantly different from those of firms that received no transfer (Table A.11, columns 1, 3, and 5). By contrast, value added and TFPQ of firms that also received a know-how transfer were, respectively, 41.5% and 38.4% higher than that of firms that received only a physical capital transfer in 1985; and 52.0% and 48.3% higher between 1998 and 2013, with no statistically significant differences in employment (Table A.11, columns 2, 4, and 6). The magnitude of the estimates on the full sample are similar to those obtained from the steel sample, which indicates that our results could be extended beyond the steel industry.

6 Firm Upgrading

The fact that the effects of Soviet technology transfer persisted only if complemented by the Soviet know-how transfer is consistent with the capital-skill complementarity hypothesis (Griliches, 1969; Krusell et al., 2000): technologically advanced capital goods and high-skilled workers are relatively more complementary than capital and unskilled labor. However, since high-skilled workers are instrumental in firm upgrading, a greater availability of both these inputs should stimulate quality and technology upgrades (Verhoogen, 2023), a potential mechanism behind our results.

We empirically test this intuition in three steps. First, we check whether the transfers affected the quality of steel produced by the 304 steel plants. We find weak evidence that plants that received the physical capital transfer produced more crude steel (considered the best-quality steel) and reduced the quantities of pig iron (considered to be lower quality, given its higher carbon content) up to ten years after the intervention, relative to plants that received no transfer, and no effects after that (Table 3, columns 1–2). Conversely, plants that also received a know-how transfer produced 5.7% to 23.2% more crude steel relative to plants that received only the physical capital transfer, and 4.7% to 17.2% less pig iron between five and 20 years after the transfer, respectively (Table 3, columns 1–2).

While these findings suggest that the know-how transfer improved production quality, it remains possible that part of such output was not usable downstream, especially in light of the well-known quality issues in command economies (Perkins, 2014; Hirata, 2018). To address this potential concern, we show that plants that also got the know-how transfer reduced scrapped output due to low quality over time between 7.2% and 16.3% relative to plants that received only the physical capital (Table 3, column 3). Moreover, the percentage of defective products rejected by downstream firms decreased between 5.6% and 19.1% in the former compared to the latter (Table 3, column 4). This finding indicates that their higher

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1, when the dependent variable is TFPQ we also include product type indicators.

product quality was not only recorded internally but also acknowledged by downstream companies.[29]

The difference in product quality among firms that used the same physical capital can be related to the Soviet training. For instance, Soviet experts introduced quality-control methods that reduced the time to determine hot-metal chemical composition from 50 minutes to two minutes through systematic sampling. This procedure allowed for quality checks during the steelmaking process, rather than at the end, which reduced waste and scrapped output (Clark, 1973). Consistent with the historical evidence, we find that the amount of coke required to produce each ton of good-quality hot metal—known as the comprehensive coke ratio and commonly used as a measure of plant efficiency—differentially dropped in plants that received the Soviet know-how, indicating a *higher* operational efficiency (Table 4, column 1). Soviet experts also taught Chinese industrial engineers how to properly maintain machinery and equipment, with the goal of increasing the furnaces' annual operating hours and overall lifespan. These practices were considered "as important as production itself" in state-of-the-art steel plants at that time and impressed even U.S. experts who visited China in the late 1950s (Clark, 1973). Consequently, plants that also received the know-how improved their capital operations: their share of preventive maintenance interventions out of the total annual maintenance interventions substantially increased relative to plants that received only physical capital, while unexpected machine downtime hours out of total annual available operational hours differentially dropped (Table 4, columns 2–3). While these practices required some degree of organizational effort, they were not prohibitively costly and could be implemented within the firm and despite the constraints imposed by the command economy. Crucially, they were also fully consistent with the prevailing output-maximization objectives of SOEs, since they had the ultimate goal of increasing production. The increased production using substantially the same inputs as other firms drove the increase in TFPQ in SOEs that received the Soviet know-how relative to those which received only Soviet physical capital. Another concern could be that plants that received both physical capital and know-how may have produced higher-quality items for which, however, there was no downstream demand (Hirata, 2018). The fact that their steel-inventory level was between 8.1% and 21.2% lower than that of the other plants does not support this hypothesis (Table 4, column 4).

Second, we test the role of the know-how transfer in promoting technology upgrades. As mentioned earlier, in the 1960s and 1970s plants were entitled to retain a share of profits and to spend that money on technology adoption and equipment renewal. By contrast, large investment projects were decided by the central government (Perkins, 2014). During the 1960s, a new steelmaking process—the basic oxygen process, which blew oxygen through molten pig iron to lower the alloy's carbon content—became predominant (Clark, 1973). According to historical records, plants that received the know-how transfer were able to domestically develop and adopt this process innovation (Ji, 2019). Consistently, data on the production processes used in the steel industry indicate that plants that also received the

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[29] Reestimating TFP using physical output net of scrapped output or physical output net of steel declared unusable downstream leads to larger estimates than our baseline ones, further confirming that our results are driven by output of good-quality steel and not by output of unusable steel (Table C.3, rows 10 and 11).

know-how transfer were substantially more likely to rely on this process relative to plants that received only the physical capital transfer (Table 3, column 3). However, the latter were not more likely to use this technique relative to plants that received no transfers at all.

The Soviet physical capital was state-of-the-art in the 1950s, but by the late 1960s, due to the development of continuous casting furnaces, it had become obsolete (Fruehan et al., 1997).[30] Plants that received the know-how transfer were considerably more likely to adopt continuous casting furnaces that replaced Soviet capital relative to plants that received only physical capital from 10 to 20 years after the Soviet transfer (Table 3, column 4).[31] Conversely, the latter did not show more-continuous casting furnace usage than plants that got no transfer. These findings appear related to an important component of the know-how transfer. Part of the training promoted the development of internal research labs to discover new, more-efficient production methods and technologies (Gangchalianke, 2002).

These results raise two questions. First, was the share of profits that SOEs which received the Soviet transfer enough to finance these small investment projects? Second, did SOEs' managers have incentives to promote technological upgrades given the command economy context in which they operated? Regarding the first question, our data indicate that between 1952 and 1983 the 304 plants retained between 6.7 and 15.8 percent of their profits. Average annual profits for these plants over this period were 114.44 million yuan, implying retained profits of approximately 7.67 to 18.08 million yuan per year. According to estimates in Angang's chronicles (Weiyuanhui, 1991), the cost of developing and introducing the basic oxygen process was 26 million yuan, while producing a continuous casting furnace required 44 million yuan. Although retained profits could not be devoted exclusively to technological upgrades and such upgrades likely involved additional expenditures, the magnitudes suggest that the cost of major technological improvements could be achieved with six years of profits retention, which is not out of proportion with plant financial resources. Therefore, profit retention margins appear broadly consistent with the scale of investment required for firm upgrading.

Regarding the second question, technological upgrading contributed to higher output—the main performance target of Chinese firms. As a result, efforts to improve technology were largely aligned with existing managerial objectives. Moreover, to gain international recognition and prestige, the Chinese government aimed at increasing the country's technological level. To do so, it created non-monetary incentives: high-achieving workers, managers and even entire plants could receive formal recognition and material bonuses. These bonuses could include first-class supplementary food allowances (additional meat, eggs, oil, sugar, milk, etc), scarce consumer goods (for instance, televisions or bicycles) or other privileges. Although these awards were partly tied to political or ideological merit, they may have provided additional motivation for managers to improve their factories' performance within the constraints of the system. Furthermore, when major technical breakthroughs happened, workers were publicly praised by the People's Daily, which was the ultimate recognition at

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[30] Continuous casting furnaces solidified molten metal into a "semifinished" billet, bloom, or slab for subsequent rolling in the finishing mills. Prior to that, steel was poured into stationary molds to form ingots. Continuous casting furnaces improved output, quality, productivity, and cost efficiency.

[31] This is also reflected in an increase in the capital stock of the plants that received the know-how relative to plants that received only physical capital over the same period (Table A.6, column 4).

the time, demonstrating how innovation was celebrated at the national level (People's Daily, 1960).

Third, capital-skill complementarity should have increased employment of high-skilled workers (Goldin and Katz, 1998). Consistently, we find that over years, plants that received the know-how employed more engineers and high-skilled technicians and fewer low-skilled workers than plants that received only physical capital (Table 3, columns 5 and 6).[32] Such plants opened training schools for high-skilled technicians and offered within-firm training programs to their engineers (Hirata, 2018; Ji, 2019), which likely contributed to technology development. This channel was particularly important during the Cultural Revolution, when most advanced education in the country was suspended. The substantial gap in managerial and technical expertise between firms that got the Soviet know-how transfer and firms that eventually did not contribute to explain why the plants of the former outperformed those of the latter to such a degree. Chinese industrial personnel were characterized by having little management know-how and technical knowledge. In 1957 less than 35% of all engineering or technical personnel in Chinese factories had an education beyond technical middle school (Walder, 1984, p. 50). Consistently, we do not observe differential changes in human capital composition between plants that received Soviet physical capital and those that did not receive any Soviet transfers.

Taken together, these results suggest that complementarities between Soviet technology and engineering know-how helped the receiving plants to upgrade, in terms of both product quality and subsequent technology development. This channel helps explain why the effects of physical capital and know-how transfers were long-lasting, while the impact of physical capital alone was short-lived. While our baseline results on production and productivity are large, in this context, even relatively limited organizational and process improvements and technological upgrades could translate into large increases in output, given the initially low baseline of managerial and technological level of Chinese SOEs.

Notably, the influence of Soviet know-how on Chinese steel production persists today. According to the World Steel Association, in 2022 six of the ten largest steel producers in the world were Chinese, five of which belong to industrial clusters that got Soviet know-how (WorldSteel Association, 2023). For instance, the largest and third-largest producers, China Baowu Group and Ansteel Group, belong to the Wuhan and Anshan industrial clusters, respectively; they both received the vaunted blast furnaces from the Soviet Union in the 1950s, along with extensive Soviet training and crucial management expertise (Ji, 2019; Wu and Yi, 2022). By contrast, the Tangshan cluster, which also received the Soviet blast furnaces but not the training, is not ranked among the top Chinese steel companies.

6.1 Trade With Western World After 1978

In the late 1970s, China began gradually opening to international trade, especially with the Western world. Among other consequences, this implied that Chinese plants could import machinery from the United States and Western Europe and export their products there.

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[32] Notably, the numbers of high-skilled and low-skilled workers were comparable across the three types of plants at time they opened, as we have shown in our balancing tests (Table 2, Panel A), while total employment remained comparable over time (Table A.6, column 3).

Khandelwal et al. (2013) show that the removal of quotas on Chinese textile and clothing exports to the United States, the European Union, and Canada in the 2000s led to larger-than-expected productivity growth, due to the concomitant abolition of the institutions that grew up around trade barriers. In a similar vein, we study whether trade with the Western world helps explain the further increase in performance during the 1980s and 1990s of steel plants that received Soviet know-how.

Detailed data on foreign technology imports allow us to examine whether opening to trade differentially affected the 304 plants after 1978. Specifically, from the contract descriptions, we can distinguish between imports of Western physical capital used to replace domestic ones and imports of equipment complementary with plants' capital. The results indicate that plants that received the Soviet know-how imported 17.2% less physical capital to substitute their current one, but 20.4% more foreign equipment used as a complement for their machinery, relative to plants that received the Soviet physical capital only (Table 6, columns 1 and 2). Such plants were also able to take advantage of the new export possibilities. They exported 33.9% more steel into the Western world than plants that received the Soviet physical capital only and produced 32.0% more steel above the international standards (Table 6, columns 3–4).

This finding indicates that the quality of steel produced by plants that received the Soviet know-how was recognized not only in China but also by the international steel market. By contrast, we do not observe differential imports of foreign capital and exports between plants that received Soviet physical capital and plants that eventually received no Soviet transfer. This aspect can also help explain the short-lived effect of the Soviet capital transfer. When both types of plants could import foreign machinery, plants that received Soviet capital no longer had a productivity advantage over plants that received no Soviet transfer.

7 Spillover Effects

At the core of the Big Push theory is the idea that the initial localized investments could become self-sustaining due to agglomeration economies (Kline and Moretti, 2014). Such agglomerations could be stimulated through the simultaneous installation of complementary industries, with strong backward and forward linkages, to exploit economies of scale (Murphy et al., 1989). Following this strategy, on top of the 304 steel plants that represented the bulk of steel industrial clusters, the Soviet aid involved the construction of 684 complementary plants, which were not eligible to receive the Soviet transfers. Did the 304 plants generate the spillover effects predicted by the literature?

To answer this question, we first construct the backward and forward linkages between the 304 plants and the complementary establishments, using the input-output matrix (for more details, Appendix B.2). Next, we estimate the following equation:

$$\begin{aligned}\text{outcome}_{jit} = {} & \alpha \cdot \text{Physical Capital}_i + \beta(\text{Physical Capital}_i \cdot \text{Post Transfer}_{it}) \\ & + \gamma \cdot \text{Know-How}_i + \delta(\text{Know-How}_i \cdot \text{Post Transfer}_{it}) + \theta_t + \nu_{jit}\end{aligned} \tag{3}$$

where outcome_{jit} are key metrics of performance, technology adoption, and exports of plant j with linkages with plant i in year t; the other variables are defined as in equation 1.

Plants with linkages to plants that received the Soviet physical capital produced on average 10.0% more output than plants with linkages to plants that received no Soviet transfer (Table 7, column 1). These findings are fully consistent with the increased production of plants that received Soviet physical capital, which in turn likely affected their supply chain. However, only plants with linkages to plants that also received the know-how transfer experienced both production and productivity increases after the Split, 20.3% and 19.2%, respectively and relative to plants that only got Soviet physical capital (Table 7, columns 1 and 2).

When China was a closed economy, these plants also had a higher probability of technological upgrade (Table 7, column 3). Moreover, when China opened up to international trade after 1978, it imported less physical capital to substitute its current one, but more foreign equipment used as a complement for its machinery, and it systematically engaged more in exporting to the Western world (Table 7, columns 4–6).

These results could be explained by the fact that plants that received the Soviet know-how over years offered training programs for engineers and high-skilled technicians working in their own plants and in related plants (Hirata, 2018; Ji, 2019), generating technological externalities through local interactions and learning-by-doing (Glaeser et al., 1992; Moretti, 2004). Such findings also echo previous studies that, in different settings, have documented sizable knowledge spillovers along the supply chain (Greenstone et al., 2010; Kline and Moretti, 2014; Bianchi and Giorcelli, 2022). We add to this literature by showing how, in the Chinese context, the diffusion of engineering know-how to complementary establishments generated productivity spillovers and technology upgrade, while economies of scale stemming from input-output linkages had a more limited impact.

Starting in the late 1990s, the Chinese government undertook a number of market liberalization reforms to release resources that could be more profitably employed by privatizing state-owned firms (Hsieh and Song, 2015). We therefore test whether the spillover effects persisted after market liberalization, using data on firms in all the industries between 1998 and 2013. We find that firms related to plants that received the Soviet know-how performed better in terms of value added, TFPR, and exports than firms related to plants that only received Soviet physical capital, only if they were privatized (Table A.12, Panel A, columns 1–4). Moreover, new private firms that related to plants that received the Soviet know-how had an additional performance gain relative to new firms related to plants that received only the Soviet physical capital.[33]

County-Level Analysis. To examine whether the 156 Projects generated agglomeration effects, in line with the Big Push predictions, we extend our analysis at the county level.[34] Counties that hosted plants that received Soviet know-how had on average 16.6% more private firms relative to counties that hosted plants that received only Soviet physical capital and 25.2% more privately produced industrial output (Table A.13, columns 1 and 4). Conversely, there were no differences between counties that hosted plants that received only Soviet physical capital and plants that received no Soviet transfer.

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[33] In industries not related to the 156 Projects, we do not observe any difference in performance among firms in the same counties (Table A.12, Panel B).

[34] Because this analysis is at the county-level, we can use data on all the 156 Projects, not only on the steel ones, as in Equation 3.

Next, we test whether counties that hosted plants that received the Soviet know-how had a higher concentration of industry-specific human capital. In fact, such plants opened in-house training schools for engineers and high-skilled technicians, especially during the Cultural Revolution, that were institutionalized after 1978. Into the late 1990s, universities in counties that hosted plants that received the know-how transfer were 10.4 percentage points more likely to offer STEM (science, technology, engineering, and math) university degrees and had a 15.6% higher number of technical schools per inhabitant relative to counties that hosted plants that received the physical capital transfer (Table A.14, columns 1 and 2). This was associated with a 13.3% higher number of STEM college graduates and a 16.2% higher number of high-skilled workers over population (Table A.14, columns 3 and 4).[35] When firms started competing for inputs in the local market, having more STEM and high-skilled workers at the county level could have given them better hiring opportunities, with positive effects on their performance.

The results we've presented so far are based on a comparison of plants built under the Sino-Soviet Alliance and establishments in their supply chain or their hosting counties, and rely on variation in the Soviet transfers they eventually received. A separate, interesting question would be studying the long-run spillover effects of the Sino-Soviet Alliance on other establishments in the same regions and relative to the rest of Chinese areas in more recent years. A paper closely related to ours, Heblich et al. (2022), performs this analysis and documents that counties that hosted the 156 Projects had a significant production advantage in the 1980s, relative to counterfactual counties that were suitable for hosting the projects but were ultimately not selected. However, this advantage was fully eroded by 2010 due to overspecialization and less innovation. While these findings seem at odd with ours, it is possible to reconcile the two sets of results. Firms which eventually received the Soviet transfers may remain successful and more productive than plants which eventually did not get any Soviet help in the long term, and establishments in their supply chain may gain benefit from their high productivity, even if their hosting regions became less productive than similar Chinese counties that did not host the 156 Projects.

Cost-Benefit Analysis. Finally, we assess whether the investment in the 156 Projects was profitable for the Chinese economy, performing a simple cost-benefit analysis between 1952 and 1978. We compute the direct costs of the 156 Projects as the sum of their total value when they were built ($80 billion in 2020 figures) and the loan China received from the Soviet Union and paid back in ten years at an interest rate of 1% ($2.93 billion in 2020 figures). However, when the Chinese leaders decided to push industrial development, they did so at the expense of the agricultural sector, a decision later referred to as "lots of guns and not enough butter." While we cannot estimate the welfare costs caused by this decision, we calculate the opportunity costs of the 156 Projects as the crowding out of the agricultural sector. Specifically, between 1952 and 1978, the agriculture sector's share of GDP decreased from 51% to 28.2%, which corresponds to an average annual reduction of $2.6 billion (in 2020 figures).

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[35] In Section 5.2, we showed that total investments, and investments in related and unrelated industries of the 156 Projects, were not statistically different between counties that hosted different types of Soviet plants between 1949 and 2000 (Table A.7, columns 1–3), which suggests that this potential channel is not driving our results.

We compute the benefits of the Sino-Soviet Alliance as the contribution to Chinese GDP by the 156 Projects, whose value added amounted to \$15.7 billion (in 2020 figures) on average per year between 1952 and 1978. Therefore, the benefits of the Soviet transfer were 2.5 times higher than the costs, confirming its essential role in Chinese early industrial development (Lardy, 1995; Zhang et al., 2006; Naughton, 2007).[36] These results are consistent with Carlin et al. (2013), who document that in command economies that were relatively poor when planning started, like China, the higher long-run GDP per capita stemming from physical and human capital investments compensated for the costs in allocative inefficiency and weak incentives for innovation. By contrast, for relative richer countries, the opposite result holds.

8 Conclusions

This paper studies the effects of technology and know-how transfers on structural transformations. We collected novel steel-plant-level data on the 156 Projects, which were sponsored by the Soviet Union to promote Chinese industrialization in the 1950s. Leveraging natural variation in the transfers eventually received by such plants—due to delays on the Soviet side combined with the Sino-Soviet Split in 1960—we find that the effects of the technology transfer persisted over decades only when properly complemented by the know-how transfer, which also stimulated quality and technology upgrades, as well as productivity spillovers in related industries.

Our work sheds new light on Big Push industrial policies, contributing to a nascent but rapidly growing literature that exploits natural experiments to study the origin of industrial development (Juhasz, 2018; Giorcelli, 2019; Lane, 2023; Mitrunen, 2025). We show that imported foreign technologies alone are not enough to stimulate economic development in the early stages of industrialization, while engineering know-how and high-skilled human capital can promote technological advancements within and across firms.

Examining China improves our understanding of structural transformations of the country that experienced the fastest industrialization in modern history among major economies (Morrison, 2019). An important advantage of our setting is the internal validity of the results, but the fact that China was a command economy until at least the 1980s limits their external validity.

Nevertheless, we argue that our findings may have implications beyond the Chinese context. First, similar industrialization policies were implemented in several preindustrial economies between the 1950s and 1980s.[37] Moreover, heavy industries, in particular steel, are regarded as strategic by most governments and therefore subject to state control, even in nonplanned economies, with goals that "do not necessarily coincide with value creation and profit maximization" (Mattera and Dilva, 2018). Finally, an increasing number of low-income African countries are planning to foster economic development by relying on industrial policy tools

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[36] More specifically, we compute the benefit-cost ratio of the 156 Projects as the ratio of total benefits of their value-added over 25 years to the sum of direct and opportunity costs as follows: billion [\$15.7*25/(\$80 +\$2.93+\$2.6*25)] = 2.65

[37] As explained in Section 2.1, Big Push development strategies comparable to the Chinese ones were sponsored by the Soviet Union in Communist countries such as Vietnam, Laos, Cambodia, North Korea, and Cuba, as well as in India, Egypt, Ghana, and Turkey.

that involve large public investments, limited competition, and a prominent role for the state in promoting economic development, similar to early-stage Chinese industrialization.[38] Notably, China itself is among the largest sponsors of such policies outside the Western world (Walter, 2021).

9 Data Availability Statement

The data and code underlying this article are available on Zenodo at https://doi.org/10.5281/zenodo.19175275

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[38] For instance, Uganda's third National Development Plan, adopted in 2020, entails a strengthened role for the state in guiding and facilitating development. Ghana and Cote d'Ivoire are considering introducing price controls, production caps, and public investments in cocoa production. Senegal, Ethiopia, Nigeria, and Gabon are aiming to catalyze industrial growth by channeling public investments to create manufacturing clusters (Walter, 2021).

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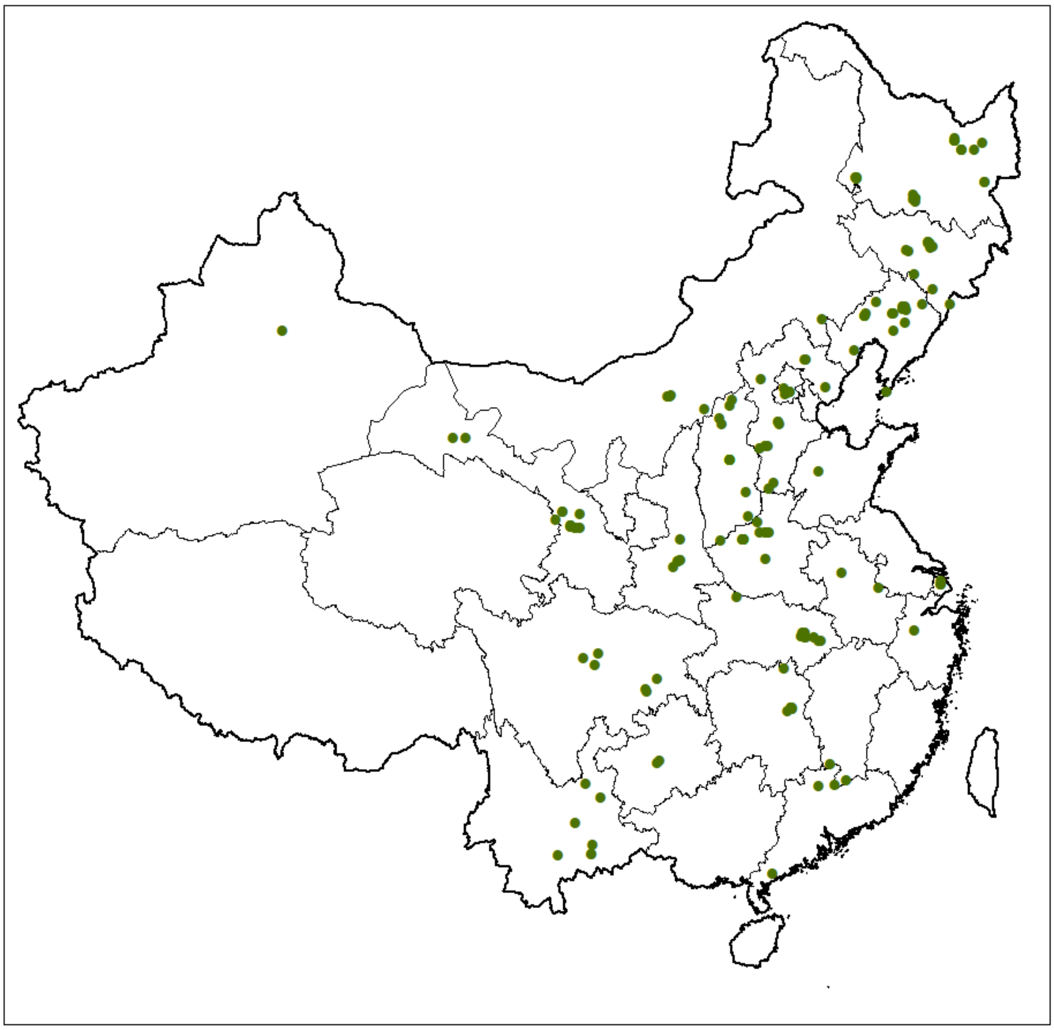
Figures and Tables

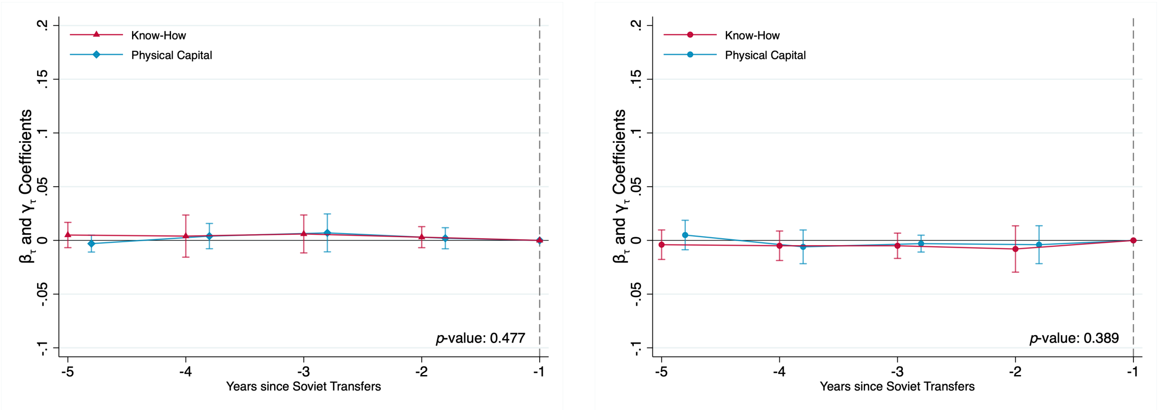
Figure 1: Geographical Distribution of the 156 Projects



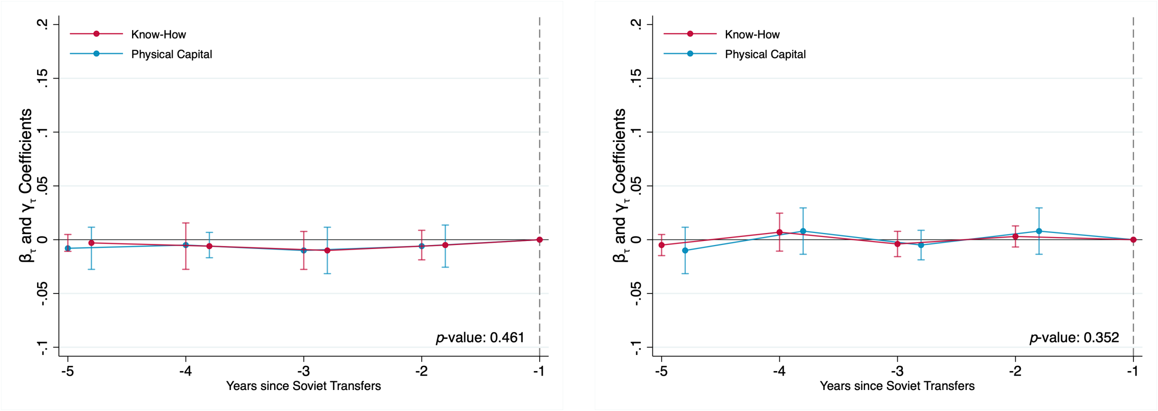
Notes. 139 approved projects between 1952 and 1957, although the iconic label 156 Projects refers to the number of projects initially contemplated. Data are provided at the project level from the National Archives Administration of China.

Figure 2: Pre-Soviet Intervention Differences in Yearly Time Trends

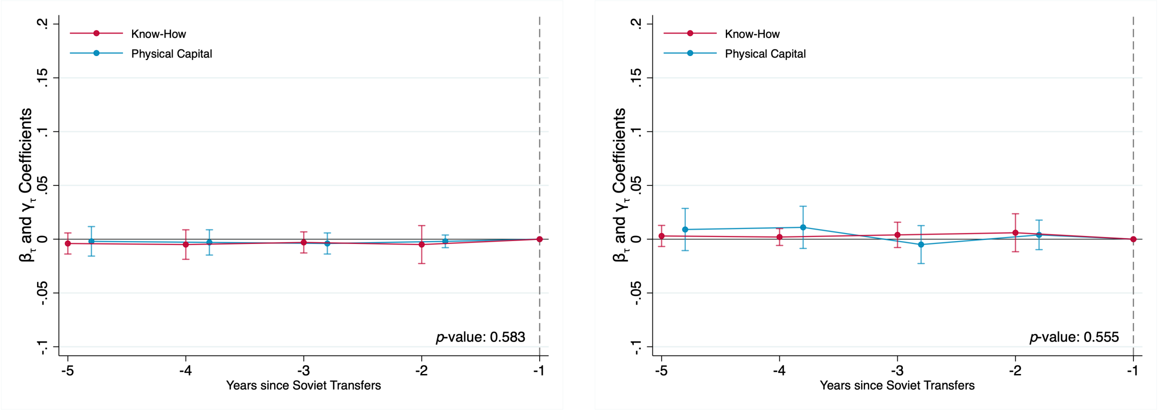
Panel A: Output Panel B: TFPQ



Panel C: Crude Steel Panel D: Pig Iron

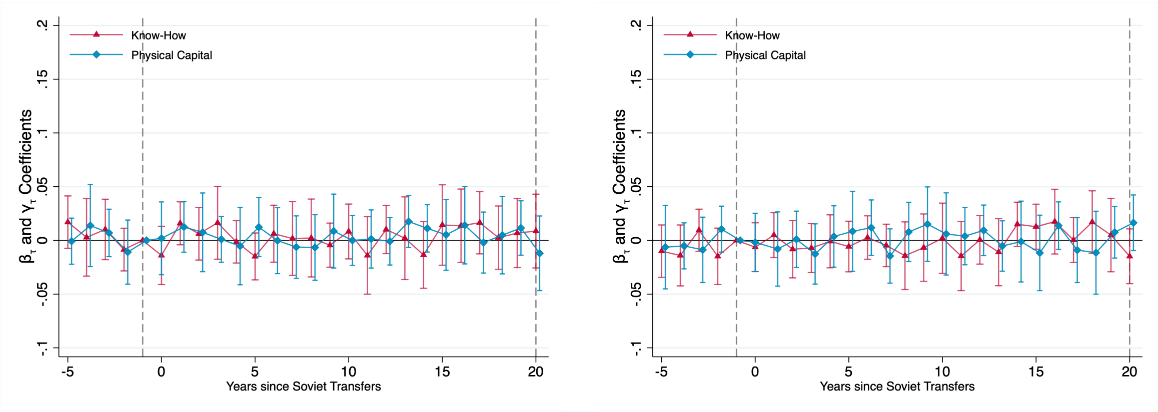


Panel E: Capital Stock Panel F: Employment



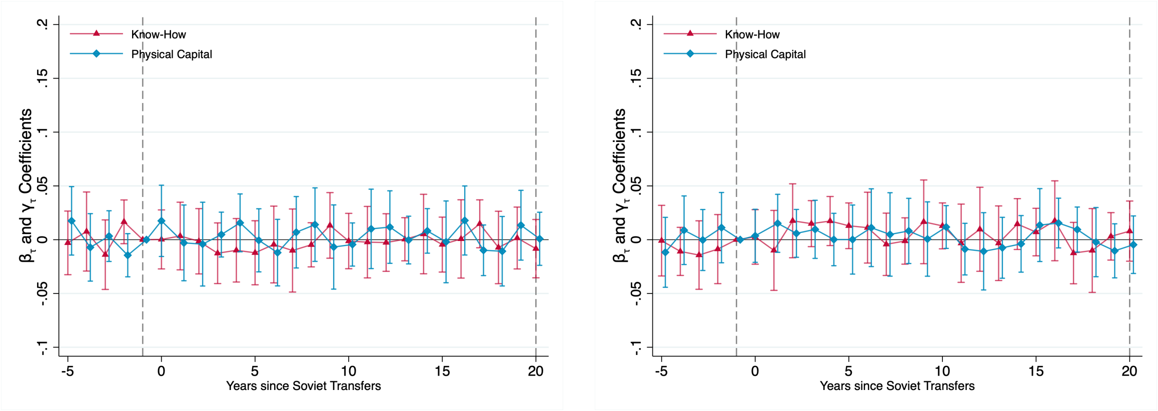
Notes. Annual β_τ and γ_τ coefficients estimated from Equation 1 for the 304 steel plants belonging to the 156 Projects, where *Physical Capital* is an indicator for plants that received Soviet physical capital. *Know-How* is an indicator for plants that also received Soviet know-how. The omitted period is $t = -1$, the year before receiving the Soviet transfer. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000. *Log Output, Crude Steel* and *Pig Iron* are logged quantities (in million tons) of steel, crude steel and pig iron. *Log TFPQ* is logged total factory productivity quantity, computed as the residuals of OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects. *Capital* is logged capital stock, calculated using the perpetual inventory method (PIM, see Table B.1). *Employment* is logged thousands of plant employees. p-value of the F-statistics testing whether all the interaction terms between physical capital and know-how and the year indicators are jointly zero are reported for each variable. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 3: Key Performance Indicators and Profit Retention in the 304 Plants



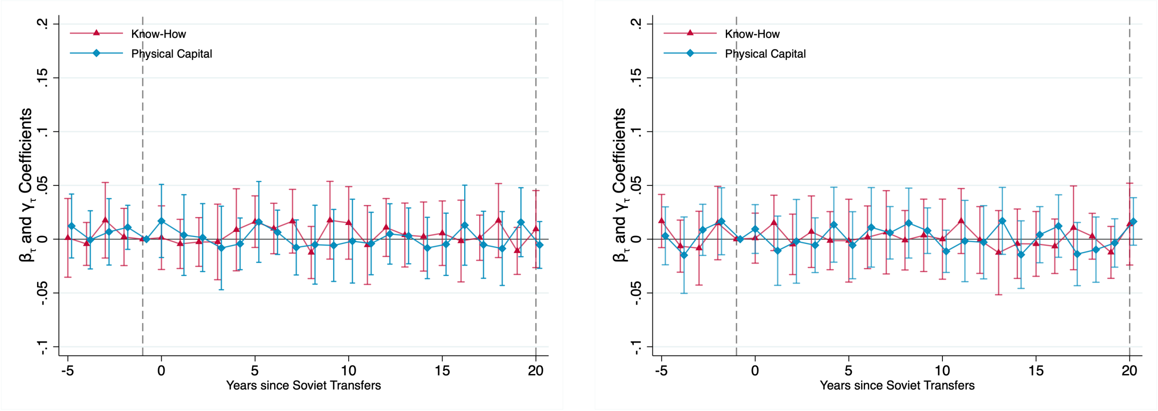
Panel A: Profits

Panel B: Product Quality



Panel C: Cost Reduction

Panel D: Total Wage Bill

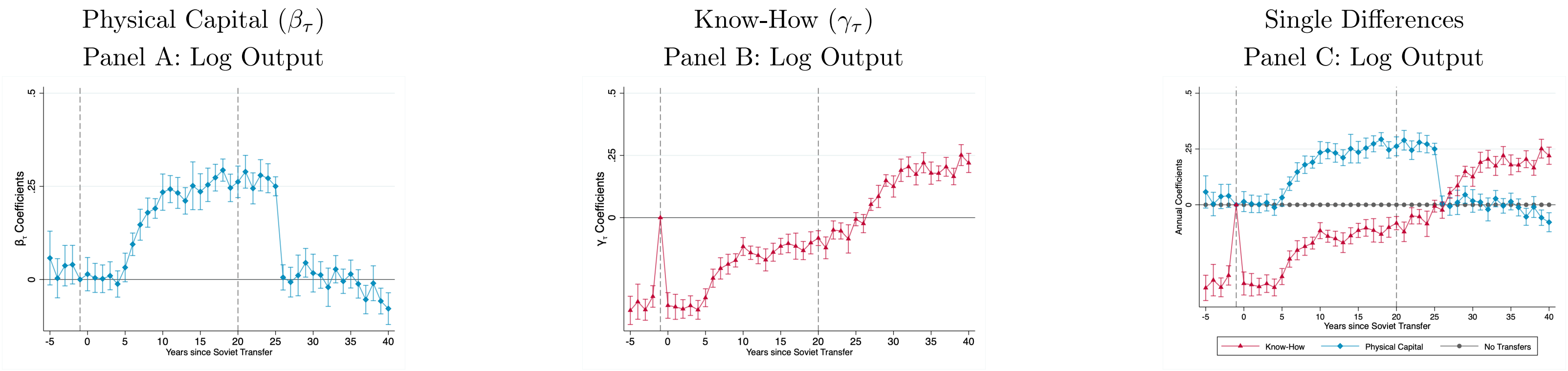


Panel E: New Products

Panel F: Share Profit Retention

Notes. *Notes*. Annual β_τ and γ_τ coefficients estimated from Equation 1 for the 304 steel plants belonging to the 156 Projects, where *Physical Capital* is an indicator for plants that received Soviet physical capital. *Know-How* is an indicator for plants that also received Soviet know-how. The omitted period is $t = -1$, the year before receiving the Soviet transfer. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000. *Profits, Product Quality, Cost Reduction, Total Wage Bill* and *New Products* equal one for plants that pursued, respectively, profits, product quality, cost reduction, total wage bill, development of new products as key performance indicator in a given year. *Profit Retention* is the share of profits plants could retain upon fulfilling key performance indicators. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

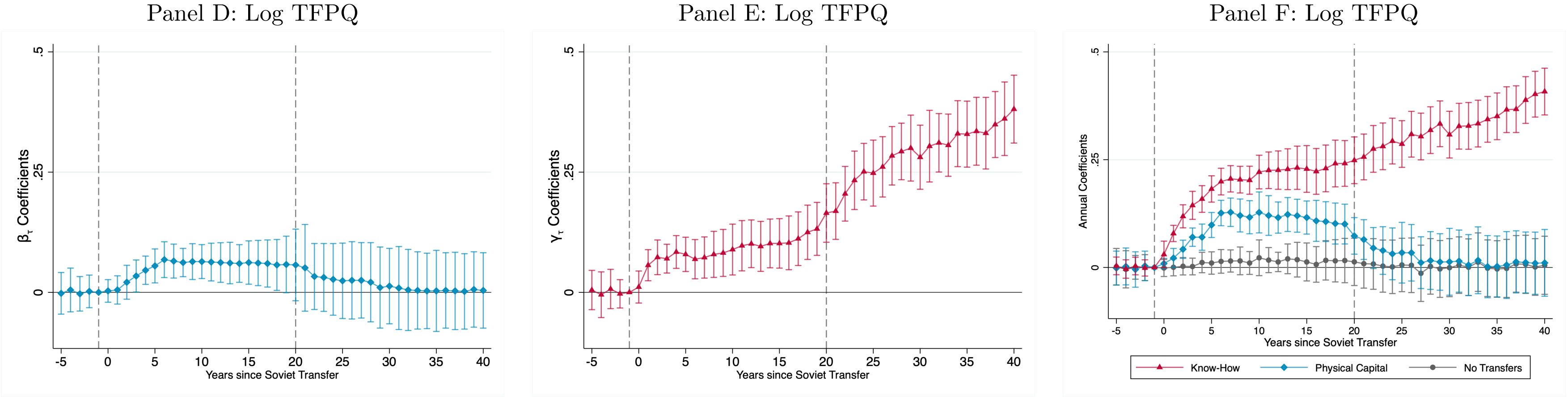
Figure 4: Yearly Effects of Soviet Physical Capital and Know-How Transfers on the 304 Steel Plants' Production and Productivity



Physical Capital (β_τ)
Panel A: Log Output

Know-How (γ_τ)
Panel B: Log Output

Single Differences
Panel C: Log Output



Panel D: Log TFPQ

Panel E: Log TFPQ

Panel F: Log TFPQ

Notes. Annual β_τ coefficients (physical capital, Panels A and D) and γ_τ coefficients (know-how, Panels B and E) from Equation 1, and single differences (Panels C and F) for the 304 steel plants belonging to the 156 Projects. The omitted period is $t = -1$, the year before receiving the Soviet transfer. Data are provided at the plant level from the Steel Association Reports from 1949 to 2000. *Log Output* is logged quantities (in million tons) of steel. *Log TFPQ* is logged total factory productivity quantity, computed as the residuals of OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects. The first vertical line identifies the beginning of the Soviet transfer. The second vertical line identifies China's opening to international trade. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications.

Table 1: Summary Statistics for the 156 Projects

	Mean (1)	SD (2)	Min (3)	Max (4)
Panel A: All Projects				
Approval Year	1953.42	1.48	1952	1957
Start Year	1955.22	1.11	1953	1958
Expected Length (years)	5.64	1.39	3	9
Expected Delivery Year, Soviet Physical Capital	1957.87	3.06	1954	1963
Expected Arrival Year, Soviet Experts	1958.62	2.77	1955	1963
Planned Investment (2020 US$ millions)	580.34	224.14	80.03	3,232.81
Actual Investment (2020 US$ millions)	549.76	215.89	91.87	3,201.93
Expected Equipment Value (2020 US$ millions)	259.35	49.76	48.79	1,340.55
Number of Workers (thousands)	39.91	14.1	25.8	70.61
Number of Plants	8.69	1.57	2	22
Observations	139	139	139	139
Panel B: Steel Industry				
Approval Year	1953.67	1.56	1952	1957
Start Year	1955.41	0.69	1952	1957
Expected Length (years)	6.12	0.72	5	9
Expected Delivery Year, Soviet Physical Capital	1957.26	2.96	1954	1963
Expected Arrival Year, Soviet Experts	1958.49	2.85	1955	1963
Planned Investment (2020 US$ millions)	746.89	361.29	167.28	3,232.81
Actual Investment (2020 US$ millions)	725.48	343.76	169.02	3,201.93
Expected Equipment Value (2020 US$ millions)	469.39	36.78	103.71	1,340.55
Number of Workers (thousands)	46.67	11.38	31.29	70.61
Number of Plants	15.20	1.33	6	22
Observations	20	20	20	20

Notes. Summary statistics for the 139 industrial clusters, known as the 156 Projects. Data are provided at the project level from the National Archives Administration of China. Columns 1–4 present, respectively, mean, standard deviation, minimum, and maximum of characteristics of all the 139 industrial clusters in Panel A and for 20 industrial clusters in the steel industry in Panel B. *Approval* and *Start Year* are the approval and start year of each project; *Expected Length* is the expected number of years to complete project construction; *Expected Physical Capital Delivery* is the project average expected year of Soviet physical capital delivery; *Expected Soviet Experts Arrival* is the project average expected year of Soviet experts arrival; *Planned*, *Actual Investment,* and *Expected Equipment Value* are, respectively, the investment planned at the approval time, the investment eventually realized, and the value of the equipment a project was expecting to receive from the Soviet Union, measured in 2020 US$ millions, reevaluated at 1 RMB in 1955=3.9605 USD in 2020; *Number of Workers(k)* is number of employees per project, in thousands; *Number of Plants* is number of plants per project.

Table 2: Balancing Tests for the 304 Steel Plants

	Mean			Tests for Mean Equality		
	Know-How	Capital	No Transfer	p-values		
				1–2	2–3	All
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Characteristics of Soviet Transfers					
Expected Equipment Value (m)	188.67	190.23	193.18	0.506	0.496	0.572
	(206.41)	(207.96)	(210.44)			
Expected Arrival of Capital	1957.31	1957.44	1957.08	0.731	0.610	0.581
	(3.45)	(3.59)	(3.12)			
Expected Arrival of Experts	1958.56	1958.78	1958.21	0.689	0.572	0.532
	(2.96)	(2.71)	(2.88)			
Share of Existing Plants	0.08	0.09	0.12	0.646	0.661	0.615
	(0.12)	(0.11)	(0.15)			
Distance Coal Deposits (km)	5.77	6.03	5.82	0.663	0.560	0.549
	(2.58)	(2.41)	(2.98)			
Distance Coke Deposits (km)	7.59	7.68	7.21	0.504	0.556	0.499
	(3.48)	(3.87)	(3.09)			
	Panel B: Production and Productivity at $t = -1$					
Output (m tons)	602.06	604.24	602.85	0.689	0.623	0.655
	(19.43)	(18.67)	(23.67)			
Productivity (log TFPQ)	1.21	1.28	1.25	0.578	0.651	0.678
	(0.32)	(0.55)	(0.25)			
Crude Steel (m tons)	153.49	152.82	154.62	0.569	0.486	0.642
	(13.98)	(14.18)	(14.23)			
Pig Iron (m tons)	96.08	101.04	99.31	0.254	0.761	0.555
	(15.18)	(15.70)	(15.12)			
	Panel C: Capital Stock and Employment at $t = -1$					
Capital Stock (m)	57.92	58.18	58.40	0.608	0.624	0.516
	(8.04)	(7.81)	(7.54)			
Employees (k)	3.49	3.60	3.44	0.453	0.532	0.492
	(1.03)	(0.72)	0.83			
Engineers (k)	0.38	0.36	0.37	0.801	0.853	0.827
	(0.04)	(0.05)	(0.05)			
High-Skilled Technicians (k)	0.51	0.57	0.52	0.497	0.563	0.647
	(0.14)	(0.36)	(0.33)			
Unskilled Workers (k)	2.60	2.64	2.62	0.578	0.489	0.542
	(1.05)	(0.75)	(0.91)			
Observations	98	91	115	189	206	304

Notes. Balancing tests for the 304 steel plants in the 20 steel industrial clusters. Data are provided at plant level from the Steel Association Reports. Columns 1–3 report mean and standard deviation (in parentheses) of characteristics and outcomes, separately for 98 plants that received both know-how and physical capital transfers from the Soviet Union (column 1), 91 plants that received only a physical capital transfer from the Soviet Union (column 2), and 115 plants that eventually received no Soviet transfers (column 3). Columns 4 and 5 report the p-value of testing mean equality between columns 1 and 2 and columns 2 and 3, respectively. Column 6 reports the p-value of testing jointly the mean equality of columns 1, 2 and 3. *Expected Equipment Value* is the value of the equipment a project was expecting to receive from the Soviet Union, measured in 2020 US$ millions, reevaluated at 1 RMB in 1955=3.9605 USD in 2020. *Expected Arrival of Capital/ Experts Year* are the expected year of arrival of Soviet capital/experts in a given plant; *Share of Existing Plants* is the share of plants built during the Japanese occupation of Manchuria. *Distance Roads/Railroads* is logged distance in km of each plant from the closest road or railroad. *Output, Crude Steel,* and *Pig Iron Production* are quantities (in million tons) of steel, crude steel, and pig iron. *Productivity (logged TFPQ)* is logged total factor productivity quantity, computed as the residuals of OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects. *Capital* is logged capital stock, calculated using the perpetual inventory method (PIM, see Table B.1). *Employees, Engineers, High-Skilled Technicians*, and *Unskilled Workers* are, respectively, thousands of employees, engineers, high-skilled technicians, and unskilled workers employed in a plant.

Table 3: Effects of Soviet Transfers on Output Quality

	Crude Steel (1)	Pig Iron (2)	Scrapped Output (3)	Quality Defect (4)
Physical Capital * Year 1	0.011	-0.018	0.002	-0.003
	(0.011)	(0.020)	(0.004)	(0.006)
Physical Capital * Year 5	0.112**	-0.106***	0.005	0.001
	(0.051)	(0.047)	(0.006)	(0.008)
Physical Capital * Year 10	0.082*	-0.076*	0.010	-0.005
	(0.044)	(0.041)	(0.014)	(0.009)
Physical Capital * Year 20	0.021	-0.028	0.008	-0.004
	(0.047)	(0.049)	(0.009)	(0.011)
Know-How * Year 1	0.004	-0.032	0.005	0.010
	(0.035)	(0.030)	(0.007)	(0.009)
Know-How * Year 5	0.055***	-0.048***	-0.075***	-0.056***
	(0.015)	(0.012)	(0.012)	(0.015)
Know-How * Year 10	0.178***	-0.138***	-0.151***	-0.115***
	(0.046)	(0.044)	(0.045)	(0.044)
Know-How * Year 20	0.209***	-0.189***	-0.178***	-0.191***
	(0.049)	(0.048)	(0.043)	(0.052)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ and γ_τ coefficients from Equation 1 for the 304 steel plants belonging to the 156 Projects. *Physical Capital* is an indicator for plants that received Soviet physical capital. *Know-How* is an indicator for plants that also received Soviet know-how. Data are provided at the plant level from Steel Association Reports from 1949 to 2000. *Crude Steel, Pig Iron,* and *Scrapped Output* are logged quantities (in million tons) of crude steel, pig iron, and output scrapped due to low quality. *Quality Defect Index* is the fraction of plant output rejected by downstream firms due to low quality. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Effects of Soviet Transfers on Capital and Factory Operations

	Coke Ratio (1)	Maintenance (2)	Down-Turn Time (3)	Inventory (4)
Physical Capital * Year 1	0.006	0.008	0.005	0.006
	(0.005)	(0.012)	(0.008)	(0.013)
Physical Capital * Year 5	0.009	0.009	0.003	0.006
	(0.010)	(0.011)	(0.007)	(0.011)
Physical Capital * Year 10	0.009	0.007	0.003	-0.005
	(0.010)	(0.015)	(0.010)	(0.007)
Physical Capital * Year 20	0.007	0.005	0.005	-0.008
	(0.009)	(0.008)	(0.005)	(0.011)
Know-How * Year 1	0.003	0.010	0.005	-0.029
	(0.010)	(0.008)	(0.007)	(0.030)
Know-How * Year 5	-0.105***	0.149***	-0.181***	-0.085***
	(0.029)	(0.028)	(0.043)	(0.018)
Know-How * Year 10	-0.155***	0.288***	-0.198***	-0.198***
	(0.045)	(0.029)	(0.045)	(0.040)
Know-How * Year 20	-0.231***	0.297***	-0.222***	-0.238***
	(0.052)	(0.031)	(0.044)	(0.055)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ and γ_τ coefficients from Equation 1 for the 304 steel plants belonging to the 156 Projects. *Physical Capital* is an indicator for plants that received Soviet physical capital. *Know-How* is an indicator for plants that also received Soviet know-how. Data are provided at the plant level from Steel Association Reports from 1949 to 2000. *Coke Ratio* is the comprehensive coke ratio, defined as the ratio between coke usage and total tons of hot metal production. *Maintenance* is preventive machine and equipment maintenance, defined as the ratio between planned maintenance interventions and total maintenance interventions. *Down-Turn Time* is the ratio between unexpected machine downtime hours and total available operational hours over a year. *Inventory* is measured in logged tons of steel. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Effects of Soviet Transfers on Technology Upgrade and Human Capital

	Technology Upgrade		Human Capital	
	Converters (1)	Casting (2)	High-Skilled (3)	Unskilled (4)
Physical Capital * Year 1	0.006	0.005	0.002	-0.003
	(0.005)	(0.009)	(0.003)	(0.005)
Physical Capital * Year 5	0.009	0.007	0.005	0.003
	(0.010)	(0.008)	(0.006)	(0.005)
Physical Capital * Year 10	0.009	0.006	0.013	0.015
	(0.010)	(0.008)	(0.015)	(0.020)
Physical Capital * Year 20	0.007	0.010	0.011	0.011
	(0.009)	(0.014)	(0.013)	(0.010)
Know-How * Year 1	0.003	0.008	0.004	0.005
	(0.010)	(0.011)	(0.006)	(0.008)
Know-How * Year 5	0.252***	0.019	0.026***	-0.025***
	(0.041)	(0.013)	(0.007)	(0.004)
Know-How * Year 10	0.345***	0.267***	0.053***	-0.060***
	(0.053)	(0.051)	(0.007)	(0.007)
Know-How * Year 20	0.651***	0.784***	0.068***	-0.071***
	(0.151)	(0.143)	(0.007)	(0.006)
Observations	7,904	7,904	7,904	7,904

Notes. Selected annual β_τ and γ_τ coefficients from Equation 1 for the 304 steel plants belonging to the 156 Projects. *Physical Capital* is an indicator for plants that received Soviet physical capital. *Know-How* is an indicator for plants that also received Soviet know-how. Data are provided at the plant level from Steel Association Reports from 1949 to 2000. *Converters* and *Casting* are indicators for plants using the basic oxygen converters and the continuous casting furnaces. *High-Skilled* and *Unskilled* are logged thousands of engineers and production supervisors, and unskilled employees. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Trade With Western World After 1978

	Substitute Capital (1)	Complementary Equipment (2)	Exports (3)	Int. Stand. (4)
Physical Capital	0.012	0.013	0.014	0.010
	(0.009)	(0.010)	(0.018)	(0.012)
Know-How	-0.159***	0.186***	0.292***	0.278***
	(0.048)	(0.051)	(0.041)	(0.043)
Observations	9,120	9,120	9,120	9,120

Notes. Physical Capital is an indicator for plants that received Soviet physical capital. *Know-How* is an indicator for plants that also received Soviet know-how. Data are provided at the plant level from the from Steel Association Reports from 1949 to 2000 and from the Chinese Ministry of Commerce and the Ministry of Industry and Information Technology from 1970 to 2000. *Substitute Capital, Complementary Equipment, Exports,* and *Int. Stand.* are logged values of foreign imported capital used to replace Soviet capital, foreign equipment complementary with plant physical capital, exports, and quantity of steel that met international standards. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Effects of Soviet Transfers on Complementary Firms

	Log Output (1)	Log TFPQ (2)	Tech. Upgrade (3)	Subs. Capital (4)	Compl. Equipment (5)	Log Exports (6)
Physical Capital	-0.008	-0.009	0.003	0.006	0.005	0.009
	(0.015)	(0.014)	(0.005)	(0.011)	(0.008)	(0.012)
Know-How	0.006	0.005	0.006	-0.088***	0.077***	0.164***
	(0.010)	(0.011)	(0.008)	(0.021)	(0.019)	(0.035)
Physical Capital * Post	0.095***	0.012	0.009			
	(0.028)	(0.014)	(0.010)			
Know-How * Post	0.185***	0.176***	0.322***			
	(0.035)	(0.033)	(0.106)			
Observations	27,360	27,360	27,360	13,680	13,680	13,680

Notes. *Physical Capital* is an indicator for complementary plants with linkages with plants that received Soviet physical capital. *Know-How* is an indicator for complementary plants with linkages with plants that also received Soviet know-how. Data are provided at the plant level from the from Steel Association Reports from 1949 to 2000 and from the Chinese Ministry of Commerce and the Ministry of Industry and Information Technology from 1970 to 2000. *Post* is an indicator for years after receiving the Soviet transfers; *Log Output* is logged quantities (in million tons) of steel; *Log TFPQ* is logged total factor productivity quantity, computed as the residuals of OLS regression of plant logged physical output on logged workers, capital stock and inputs, and plant and year fixed effects; *Tech. Upgrade* is an indicator for plants that adopt a new technology or production technique, or develop a new product or a new process; *Subs. Capital, Compl. Equipment,* and *Log Exports* are logged values of foreign imported capital used to replace existing capital, foreign equipment complementary with plant physical capital, and exports. This data is only available for the years after the Soviet transfers, therefore columns 4-6 are estimated in the post Soviet transfer period only. Standard errors are block-bootstrapped at the industrial cluster level with 1,000 replications. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.