# Heading Off Track: The Impact of China's Mercantilist Policies on Global High-Speed Rail Innovation

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Chinese high-speed rail firm CRRC is less innovative than European and Japanese firms, but mercantilist policies help it dominate in China and expand globally. This starves superior firms of revenue, reduces their R&D, and slows the pace of global innovation.

## KEY TAKEAWAYS

- China's state-directed bid for a leadership position in the high-speed rail sector has distorted the global market with massive subsidization, mandated mergers, forced technology transfers, and other mercantilist practices.
- With its vast resources, China could have financed win-win trade and innovation. Instead, it pursued zero-sum mercantilism, closing its own market and subsidizing its rail firms to help them take advantage of open foreign markets.
- There are only a few large high-speed rail projects at any one time worldwide. It's critical that they go to market- and innovation-driven firms, not state-driven players like CRRC.
- CRRC is already working on high-speed projects in developing countries, and with its state backing it is now tirelessly pursuing its first big prize in a developed country.
- The huge diversion of global market share and revenue to CRRC has helped it catch up to its competitors. But each project lost to CRRC means fewer new patents and technologies from the world's most innovative high-speed rail firms.
- If CRRC's global market share was 15 percent instead of 70 percent, then non-Chinese high-speed rail firms would have doubled the number of U.S. rail patents.
- Canada, Europe, Japan, Korea, and the United States need to restrict Chinese rail firms and products in domestic procurement markets while supporting R&D, trade, and market opportunities for innovation-driven high-speed rail firms.

## CONTENTS

## INTRODUCTION

High-speed rail is a technology-driven sector that has taken decades for the leading Japanese and European firms, and the broader ecosystem of component suppliers in the United States and elsewhere, to master. Yet, over the previous 20 years, China used mercantilist policies to rapidly and unfairly close the gap. For example, it used the development of its massive high-speed rail network to unfairly seize foreign technology and know-how to support its local champion, CRRC, and other rail firms. This diverted huge amounts of revenue that, had China's high-speed rail network been based on comparative advantage and market-based industrial development, would have otherwise gone to leading foreign firms.

The impact continues to grow as China supports CRRC's efforts to seize global market share. Chinese rail firms are increasingly competitive with foreign rail firms but remain less innovative. By taking global market share from these more-innovative firms, China's rail industrial policy continues to detract from innovation in the high-speed rail sector, which otherwise would be developing better, cheaper high-speed rail systems.

**Chinese rail firms are increasingly competitive with foreign rail firms but remain less innovative.**

China could just as easily have used its vast financial resources to import foreign rail products and rail systems. But it did not want to do that, even as it ran massive trade surpluses with the rest of world. It could have attracted foreign firms to set up their own local production and research facilities as part of a normal pattern of foreign trade, investment, and industrial development. Instead, it wanted local firms to control the rail sector. Over time, China's mercantilist policies evolved as its firms became more competitive. It ratcheted up restrictions to help those firms move up the value chain and throughout the sector from freight to light rail and metro to large and fast passenger trains, before ultimately getting to the crown jewels: high-speed rail. China wanted to build up its own high-speed rail industry, to sell not only in China but around the world.

China did this through an array of unfair, mercantilist practices. In violation of World Trade Organization (WTO) rules, China linked domestic rail contracts to forced foreign technology transfers. (Local content requirements are common in large rail projects, but forced technology transfers are not). It also compelled two state-owned rail companies to merge to create China's national-champion CRRC, which has about 95 percent of China's high-speed rail market, with Bombardier a distant second through its forced joint venture (JV) with CRRC.[1] Over time, local procurement rules increasingly penalized bids involving foreign firms, products, and technology, channeling more procurement contracts to local firms and technology. China also provided huge subsidies and other financial support to domestic firms such as CRRC to not only expand in China, but to "go out" and seize global market share.

Outside of China, the major firms are Alstom (France), Bombardier (Canada, which Alstom recently acquired), Hitachi (Japan), Hyundai Rotem (South Korea), Kawasaki Heavy Industries (Japan), and Siemens (Germany). There are relatively few of these firms, as it takes large and long-term investments in research and development (R&D) and CapEX to develop the necessarily technology and train systems. These companies lead consortiums of other rail firms and component suppliers as part of their bids for government rail contracts. This makes China's mercantilist approach to high-speed rail especially damaging, as there are few opportunities for these firms and their component suppliers to earn the revenue that further supports innovation in a highly specialized set of technologies. More of the Chinese and global market for high-speed rail would have otherwise gone to these foreign firms—which did, and in many areas still do, lead in terms of advanced rail technology—had they been able to enter and compete on fair terms. If China had taken a more open and collaborative approach, it would have contributed, rather than detracted, from high-speed rail innovation.

The first section of this report summarizes innovation in high-speed rail, including a case study on magnetic levitation (maglev) technology. The second section analyzes the growing impact China's approach has had on global markets and foreign firms in Japan, Europe, and the United States. The third section delves into China's embrace of mercantilist policies for high-speed rail, especially forced technology transfers, massive financial support for domestic high-speed rail firms, discriminatory procurement and market access rules, and its creation of a monopolistic national champion, CRRC. It includes a case study of how China uses "hidden" market barriers in the rail sector to disadvantage foreign firms and products. The report includes two annexes about Kawasaki's battle to keep hold of its technology in China, and CRRC and other Chinese rail firms' global acquisitions of foreign rail firms.

The fourth section analyzes how China's high-speed rail mercantilism has gone global and how CRRC and other rail firms have entered and started competing for a growing share of developed and developing country markets. The report includes an annex that details CRRC's entry into Europe and what this reveals about its strategy to seize market share in global markets. The fifth section provides a qualitative and quantitative assessment of comparative innovation in the high-speed rail segment among Alstom, CRRC, Hitachi, Kawasaki, and Siemens in looking at R&D spending and patents. It also includes an estimate as to the impact CRRC's siphoning of revenue and market share has had on Alstom's (its main high-speed rail competitor) R&D capabilities in terms of patents.

The report concludes by providing a range of recommendations for policymakers from the Americas, Asia-Pacific, Europe, and elsewhere to push back on China's high-speed rail mercantilism both at home and abroad. Recommendations are divided between measures to restrict China and those that are needed to support market- and innovation-driven firms.

**Restricting China and CRRC:**

- Countries should block Chinese acquisitions of local rail firms due to Chinese firms benefitting from stolen intellectual property (IP) and huge financial subsidies. In particular, the EU should help individual member states improve their foreign investment screening frameworks.
- Countries should use the considerable powers they have over domestic procurement contracts to exclude Chinese rail firms and work together toward fairer international procurement markets. Public procurement plays a major role in high-speed rail projects, which gives governments a mechanism to promote innovation while screening out bidders for technology theft, unfair state-based financial support, and non-reciprocal market access.

- Countries should push the World Bank to stop all rail-related funding in China and its engagement with Chinese firms in rail projects elsewhere around the world.

**Supporting domestic innovation and market-driven firms:**

- Countries should provide more low-cost and easy-to-access export financing to help local rail firms compete with CRRC and other Chinese rail firms for foreign projects and sales. Large amounts of such long-term financing are one of China's main tools for seizing market share around the world.
- Countries should provide financial incentives to host, and help local firms send experts to, international standards discussions related to high-speed rail. The development and use of standards play a critical role in high-speed rail projects.
- Given the state-sponsored nature of CRRC (and other Chinese rail firms), countries should consider allowing their own rail firms to merge to ensure they're in a better position to compete.
- Countries need to provide more funds as part of a long-term supportive R&D framework for rail firms.

## HIGH-SPEED RAIL TECHNOLOGY AND INNOVATION: THE PAST AND FUTURE

High-speed rail is a complicated technology that has long been a symbol of economic and innovation prowess. The International Union of Railways defines high-speed rail as systems of rolling stock and infrastructure that regularly operate at or above 250 kph (155 mph) on new tracks or 200 kph (125 mph) on existing tracks.[2] High-speed rail has many economic and societal benefits relative to cars and planes. It has lower operating costs and more rapidly connects people, thus enabling greater productivity across every downstream industry that leverages it. High-speed rail also reduces negative externalities such as automobile accidents, highway congestion, and greenhouse gas emissions.

China is the world's largest market for high-speed rail. It is home to over two-thirds of the world's high-speed rail lines and operates by far the world's largest high-speed train service, with over 2,600 pairs of high-speed trains running every day.[3] This is all the more astounding given China only opened its first fully high-speed rail line in 2008. Since then, China has opened thousands of kilometers of high-speed lines with speeds ranging from 200 to 350 kph.[4] To do this, China spent hundreds of billions of dollars on the world's most expensive public-works project since President Eisenhower's Interstate Highway System of the 1950s.[5] And China isn't finished. In May 2020, the China State Railway Group (CSRG)—which owns all high-speed rail services in China—announced plans to link all major cities with more than 500,000 people to the high-speed rail network.[6] In August 2020, it announced plans to double the length of China's high-speed rail network to 70,000 km by 2035.[7] As part of both economic-stimulus and industrial-development plans (including the Made in China 2025 plan, among others), China has provided hundreds of billions of dollars to mainly Chinese firms to build and operate the network and to fund its firms to develop and manufacture the full range of goods and services that go into integrated high-speed rail projects.

No doubt, China's massive high-speed rail network has had a major positive economic, social, and environmental impact. The World Bank estimated that the economic rate of return of China's high-speed rail network in 2015 was 8 percent, well above the opportunity cost of capital in China and most other countries.[8] However, it's how China has pursued this strategy that is of legitimate concern for both its trading partners and foreign firms dedicated to competing based on innovation.

As CRRC became larger and more technologically advanced—on the back of foreign technology and know-how—China adapted its domestic restrictions to grow market share for local firms and technology. Foreign rail firms were largely restricted to providing components (also via forced JVs) as part of a shrinking market as China pursued ever-expanding control of technology throughout the sector, strategically picking and supporting local firms to provide copycat replacements for foreign technology, especially through ever-more-restrictive local procurement criteria. For example, in its 2020 World Rail Market Study—the only global assessment of the sector—the European rail industry association UNIFE (Union des Industries Ferroviaires Européennes) regarded the Chinese market as having been only 17 percent accessible for the period of 2017–2019, down 70 percent from 63 percent for 2009–2011. For comparison, the current accessibility rate in the European market is 79 percent.[9]

**China pursues mercantilism despite having the financial resources to abide by the rules and norms of win-win global trade and innovation.**

China goes far beyond the supportive industrial policies used in other countries, such as through tax and R&D policies. Its impact on the global high-speed rail market is unique due to the size and scale of its planning and financing, the importance of its domestic procurement market for global high-speed and general rail products, of its being on both sides of many projects (in terms of state-owned enterprises (SOEs)bidding for government contracts), and its willingness to use unfair and discriminatory rules to support local firms and technology. China pursues mercantilism despite having the financial resources to abide by the rules and norms of win-win global trade and innovation. It does this as it is guided by a different overarching goal: to control technologies in sectors it identifies as strategic, such as high-speed rail.

High-speed rail technology is extremely complex and generally takes a long time to master. The railway sector is like other innovation-driven sectors in that it involves high fixed costs and capital intensity, and, for the high-speed rail segment, is driven by the need for constant innovation, rather than focused on the marginal costs of its current products. In Europe, the railway supply industry (firms that sell trains and equipment to rail service companies) invests about 3 percent of sales in R&D, but high-speed rail firms typically invest between 5 and 10 percent.[10] The manufacture of locomotives and rolling stock(i.e., railway vehicles, including both powered and unpowered vehicles such as locomotives, railroad cars, coaches, and private railroad cars and wagons) is an IP-intensive industry.[11]

High-speed rail represents an innovation-driven industry given the need for faster, safer, quieter, smoother, and more environmentally friendly trains, train networks, and services. Firms continue to invest in the many technologies involved in wheel-based fast trains, as well as in train networks and the elusive potential of maglev trains (see box 1). It also involves the drive for innovation in the broader manufacture of locomotives and rolling stock.[12] Innovation in the high-speed rail sector is both supply and demand driven. In project tenders, the rail operators define performance requirements and the industry competes to offer the best products, which usually entails integrating the most cost-effective and innovative technologies. This involves both the main rail system integrator (e.g., Alstom, CRRC, Siemens, etc.) and the many component suppliers in the supply chain. It can also be a vertical process wherein the lead company asks its suppliers for a specific output, or a bottom-up process wherein a component is designed or improved by a component supplier.[13]

Technological innovation encompasses all elements of a high-speed train system beyond just the engine and cars: platforms, bridges and tunnels, track and power supply, train and network management and signaling systems, and after-sales and maintenance services. For example, achieving ever-greater speed gets exponentially more difficult and expensive.[14] These trains need the electricity to provide the power and the motors to cope with it. Power is typically supplied by overhead wires (around 15,000 to 25,000 volts) trains make contact with via a raised arm called a pantograph. However, these wires are not rigid, but draped, as trains passing underneath distort the shape of the wire and the whole frame holding the wires. Therefore, there is significant technology that goes into just keeping the pantograph in contact with the wire. A great deal of innovation also goes into designing the bogies that house the wheels, axles, transmissions, suspension, and braking devices (whether disc or magnetic) to provide a smooth, high-speed, and quiet ride.[15] The entire operating system is supported by sophisticated on-board diagnostic and control systems.

Data and digital technologies will play an increasingly important role in helping rail meet the rising demand for safe, reliable, convenient, and environmentally friendly transport at affordable prices. Digital technologies in high-speed rail affect both the consumer end of the sector and the production and after-sales service of rail equipment. Automation, big data, and the digital transformation of the supply chain are transforming manufacturing. For example, Siemens, GE, and others are deploying 3D printing technology for rail products.[16] Digital control and signaling systems greatly enhance the reliability and performance of operations, thus eliminating the need for outdated railway signal boxes and wiring. AI-driven enterprise asset management systems make for more efficient dispatching, routing, and maintenance scheduling.[17]

Advances in automation, self-diagnosis, and real-time geolocation tracking mean trains are becoming smarter and safer. Internet of Things sensors and devices are opening new possibilities for obstacle and damage detection, preventative maintenance, and linkages with other systems, logistics agencies, and government regulators. Such smart monitoring and surveillance systems are changing the way operators manage hazards, intrusions, railway crossings, and driver behavior.[18] The digitalization of rail allows for easier integration into other sectors and initiatives, such as smart cities and a flexible, green smart grid.[19]

High-speed rail firms also innovate through new business models, such as mobility as a service, that allow the use of a single application to provide passengers with access to multiple types of transport, all via a single payment. For example, Siemens's high-speed rail line between Madrid and Barcelona is its flagship mobility-as-a-service package, as it sells predictable, affordable, and efficient transport availability (e.g., 99 percent availability), rather than just the train hardware. Siemens provides the digital services as part of a 20-year service contract for the project. However, this business model and these value-added services only work if Siemens has its hardware in place, as third-party platforms have different data protocols.[20]

## Box 1: Future Innovation: Maglev

The use of magnetic levitation—known as maglev—to propel vehicles is part of the race to develop the next generation of technology that will define and supersede the current symbol of high-speed trains: Japan's bullet trains (Shinkansen). It is mainly a Sino-Japanese battle for tech supremacy—and national pride is not an insignificant part of this contest.

With maglev, a vehicle is levitated a short distance from a guideway using magnets to create both lift and thrust. The technology goes back to 1912, when Emile Bachelet invented a magnetically levitating display model.[21] The magnets used are cooled by liquid helium or nitrogen, whose lack of friction means faster speeds and lower noise than wheeled transport. High-speed maglev trains could fill the gap between jet passenger planes (around 800 kph) and conventional bullet trains (around 350 kph). Keeping a floating train at the right distance from the track is very challenging, requiring extremely sensitive controllers to quickly adjust the magnetic field if the train moves too far from, or too close to, the track. When travelling at 600 kph, the time it takes for devices to detect and adjust the deviation on a maglev train is about one-thousandth of a second.

Beyond the challenge of developing the requisite technology, there is considerable uncertainty about the safety of high-speed maglev trains lines. And the most common argument levelled against maglev has always been cost—estimated to be about 1.5 times greater than conventional bullet trains—given projects are required to start from scratch because they cannot be integrated into a standard rail infrastructure.[22] Meanwhile, proponents of maglev technology contend that the key to affordability is the use of small, light-weight vehicles that can operate on less-expensive guideways and thus require less power for propulsion.[23]

The race to develop a commercial maglev network is not new.[24] Maglev technology has not become commonplace, in spite of its European and Japanese beginnings. Germany and Japan began conducting maglev R&D in the late 1960s and 1970s. Japan has since developed multiple test tracks, which it has gradually lengthened as part of ongoing testing and development.[25] Japan has a limited low-speed maglev rail network—the Linimo Line, which was made for the World Expo 2005—which runs at 100 kph.[26] Japan has since budgeted tens of billions of dollars to build the Chuo Shinkansen maglev line to cover the 178 miles between Tokyo and Nagoya. It will use cryogenically cooled superconducting magnets to levitate trains that run at speeds of up to 500 kmh. Early tests have shown the train could reach speeds over 600 kmh. It's targeted to start operations in 2027.[27]

In April 2020, Hitachi unveiled the latest prototype Series L0 for this line, which offers 13 percent less air resistance than the previous prototype. That older prototype used gas turbine generators to power lighting and air-conditioning, while the newer design uses a wireless connection to the ground supply.[28] Germany's first maglev train was used for an international fare in Hamburg in 1979. The country then began developing a maglev line for use to and from Munich airport, until an accident in 2006 during a test killed 23 people.[29] South Korea's first maglev line, linking Incheon International Airport to Seoul, opened in 2016. Meanwhile, the United Kingdom operated the first commercial maglev train—the Birmingham airlink shuttle—which ran from 1984 to 1995. This is indicative of how hard it has been to develop maglev technology beyond its limited use as a demonstrative, futuristic technology.

China has firmly set its sights on leading the development and deployment of maglev technology. The Ministry of Science and Technology's Advanced Rail Transit program (initiated in 2016) includes a goal to develop a 600 kph high-speed maglev transportation system. In 2019, high-speed maglev was included as a frontier key technology in China's "Outline for the Construction of a Powerful Country" and a government whitepaper, "Outline for Building China's Strength in Transport," includes an entire chapter on the development of new maglev lines between its key urban hubs.[30] China aims to put a 500 km-long high-speed maglev line into commercial use by 2025. But like every other country, China needs to do a lot more testing and then planning and development for the broader use of the technology before it is ready for network-scale commercial operations. However, experts have argued that China's maglev technology remains immature and that its one operating high-speed maglev project—the Shanghai airport line—is a financial black hole.[31]

There are many technological issues to overcome to develop and deploy high-speed maglev trains as part of an integrated transport system. There is also the overarching question as to whether there is an ideal distance and market that can leverage maglev's higher speeds at an affordable price (as compared with planes and rail-bound high-speed trains). At the moment, China's government is betting that it can do both as it throws significant financial resources and policy support behind its firms to make maglev trains happen.

Launched in 2004, China's only commercial, high-speed maglev service runs the 19 miles between Shanghai and Pudong International Airport, at 300 kph. However, it's based on foreign technology, as Siemens Transportation Systems Group built the propulsion, control, and safety systems, and ThyssenKrupp Transrapid built the vehicles and motors. With about 10,000 passengers per day, the line likely runs at a significant loss, given it cost about $1.7 billion to build.[32] Supporters of greater maglev network investment point to Shanghai's maglev train, which has operated over 100 trips a day for almost 15 years. But it is also a JV, so China does not control the underlying technology—which is explicitly what China wants to do when it deploys maglev trains at home, and no doubt, eventually overseas.[33]

Beyond this, China has several medium- and low-speed maglev trains working or planned. In 2016, it built an 18.6 km maglev line linking Changsha with Huanghua International Airport (running at 100 kph).[34] In 2018, it built a 9 km elevated maglev line serving the western part of Beijing.[35] A maglev line in Qingyuan, Guangdong Province, is due to open this year.[36] Chinese state media has reported that China is planning to develop maglev lines between Hangzhou and Shanghai, Guangzhou and Shenzhen, and Chengdu and Chongqing. In addition to the Qingyuan line, a Fenghuang County (Hunan) line will run short-distance, low-speed maglev trains that will also be operational by 2021.[37] China seems set on using foreign IP in maglev development, much as it did with wheel-based technology. In January 2021, Southwest Jiaotong University, China Railway Group, and CRRC unveiled a maglev test track in Chengdu that is based on technology Siemens and ThyssenKrupp developed for the Shanghai airport maglev track. Yet, again, this prototype track allegedly uses domestically developed technology.[38]

CRRC is developing the levitation and guidance system, the speed and location-detection system, as well as the broader control system for many of China's maglev prototypes. According to CRRC, by the end of 2020, it was to have made five high-speed maglev test vehicles. It is currently also working on building an integrated engineering system for the maglev system.[39] Yet, recent maglev projects show that it still needs foreign technology and know-how. In June 2020, Chinese media reported the test of a new maglev vehicle—designed to travel at 600 kph—on a 1.5 km test track in Shanghai.[40] The $1.3 billion project was jointly developed by Shanghai Maglev Transport Development Ltd. and a German consortium consisting of Siemens, Thyssen Transrapid, and Transrapid International.

But indicative of the shortfalls in China's propensity to create industrial overcapacity through its state-directed approach to industrial development, in 2018, Beijing ordered CRRC to halt the development of maglev production plants as part of broader orders to stop local governments from building excessive local transit projects that drive up debt and create overcapacity in industrial production. For example, CRRC's Changsha factory was expected to produce 60 maglev trains a year once completed, which is obviously much more than the global market could actually currently support.[41]

## THE COMPETITION BETWEEN CHINA, THE EU, JAPAN, AND THE UNITED STATES FOR GLOBAL RAIL PRODUCTION AND EXPORTS

The global rail industry has changed significantly over the last two decades. This section details how China and CRRC's emergence as major producers and exporters has changed the global market, and how this compares with European, Japanese, and U.S. firms and high-speed rail developments. It's important to note that the focus of this report, high-speed rail, is a proxy for the broader rail sector—which provides the foundation the major rail firms innovate and compete on. The broad rail sector includes light, metro, and regional passenger trains and freight trains. This report therefore indirectly relates to the full range of component suppliers to these various rail market segments—all of which are affected by China's mercantilist approach to high-speed rail.

### Market Size and Shares

The global high-speed rail market is relatively concentrated and only involves a few dozen countries. China, Denmark, France, Germany, Italy, Japan, Morocco, Saudi Arabia, South Korea, Spain, Switzerland, Taiwan, Turkey, and the United Kingdom all have high-speed railways.[42] Parts of the United States' "Northeast Corridor" between Washington DC, New York, and Boston operate at high speed. There are also high-speed lines in development in California, Florida, Nevada, and Texas.[43] Several developing countries have started or are considering initiating high-speed rail projects, including Egypt, India, Indonesia, Laos, and Thailand.[44] In 2020, China represented more than two-thirds (68 percent) of the world's high-speed rail network, with 35,740 km in operation. The global total is an estimated 52,000 km, out of which 10,766 km are in Europe, 1,043 km are in the Middle East, and 735 km are in North America.[45] Similarly, out of approximately 6,000 high-speed trainsets, about two-thirds are in Asia and one-third is in Europe.[46]

Based on firm and industry estimates (and limited public data), we determined that annual revenues for the high-speed rail rolling stock market (i.e., railway vehicles) were $8 billion to $9 billion annually for 2015 to 2017, and $10 billion to $11 billion for 2017 to 2019.[47] China accounted for the vast majority of this global market, estimated at around 72 percent for 2015 to 2017 and 75 percent for 2017 to 2019. Europe accounted for the majority of the remaining market share.

CRRC has the largest share of the global high-speed rail market due to its dominance of the Chinese market. It has accounted for two-thirds to three-quarters of all deliveries in the market over the last decade.[48] Alstom's, Hitachi's, Kawasaki's, and Siemens's market shares are largely due to projects in their respective home markets, and in a small number of cases, export orders. However, they have each lost relative and absolute market share as a result of mostly missing out on the large and fast-growing Chinese market. Given this shift, Alstom's, Hitachi's, and Kawasaki's market shares dropped from around 20 percent each between 2007 and 2009 (when China's first high-speed line went into operation) to less than 10 percent each from 2015 to 2020. Meanwhile, Siemens lost both absolute and relative market share during the same timeframe.

**There are only ever a few high-speed rail projects in the global market at any one time. This is why it's critically important to ensure each of these is fair and open and only involves firms that are market driven instead of state driven.**

Media reports provide supporting data for the impact of China's strategy, CRRC's emergence, and the waning fortunes of foreign firms.[49] In 2002, China reportedly invested nearly $6.3 billion in the high-speed market—for carriages, signaling equipment, and other high-tech track components—in which foreign companies competed and captured about 70 percent. In 2010, China invested an estimated $23 billion in the segment, of which foreign companies only accounted for an estimated 15 to 20 percent and earned nor more than they had in 2002.[50] At that time, foreign multinationals were still importing the most-sophisticated components, such as traction motors and traffic-signaling systems, but these components accounted for less than 20 percent of China's then-high-speed rail market.[51] More recently, (with rare exceptions) foreign firms have stated that China's high-speed rail market has been effectively closed to them for most of the last decade.

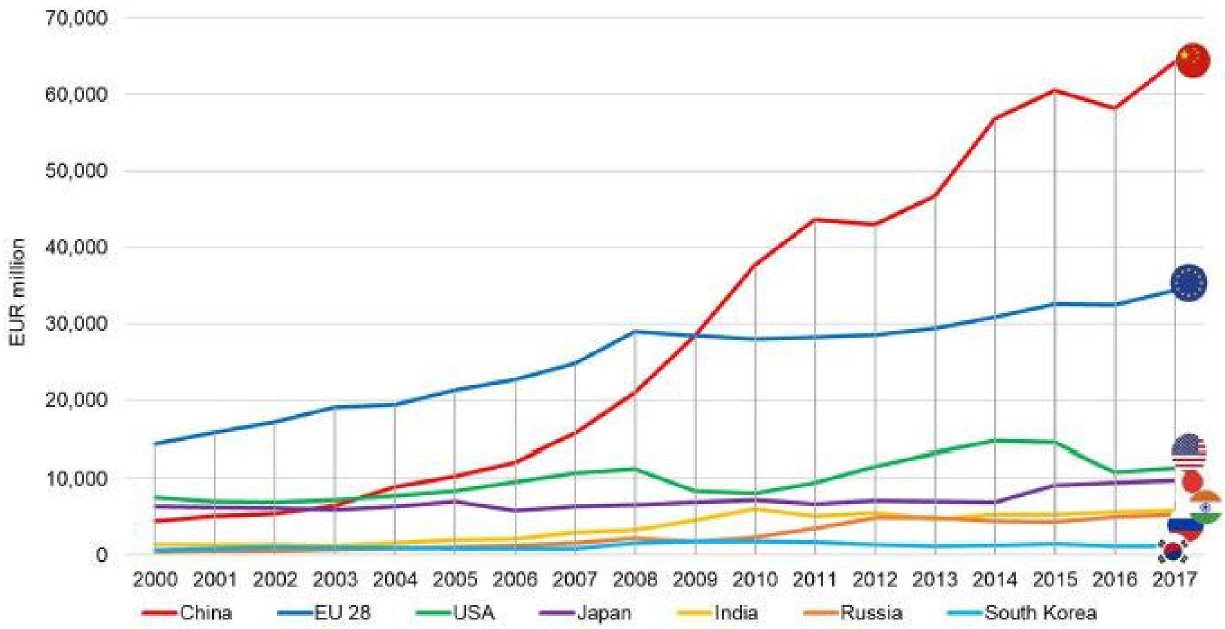
The global high-speed rail market will continue to grow, albeit at a slower pace, as compared with the dramatic China-driven growth between 2010 and 2020. The World Rail Market Study estimates average growth of 2.7 percent worldwide for the 2021–2023 period.[52] To make matters worse, global market access (as defined by the World Rail Market Study) has been decreasing over time, aggravated by rising protectionism in China (and elsewhere).[53] In 2020, there were an estimated 11,000 km of high-speed lines under construction, of which around half were in China.[54]

The global high-speed rail market is characterized by a few infrequent but large government procurement projects being open for bids and in construction at any one time, in a relatively small number of countries. Since 2008, there have been many high-speed rail projects in China (and to a far lesser extent, Japan and South Korea), but only 19 (contestable) tenders elsewhere, of which 11 were in Europe.[55] Leading high-speed rail firms feel compelled to bid on every one of the few high-speed rail projects, thus each is critically important in providing economies of scale for the large investments in production and R&D involved in high-speed rail products. This is why it's critically important to ensure each of these is fair and open and only involves firms that are market driven instead of state driven.

While Europe remains a major market and continues to expand its high-speed rail network, it faces many challenges. A 2018 audit of the EU's network was highly critical. It did not think that the European Commission's long-term plan to triple the length of high-speed rail lines—from 9,700 km in 2008 to 30,750 km by 2030—was supported by credible analysis or resources.[56] It also stated that, in reality, there was no European high-speed rail network, but rather an ineffective patchwork of national lines. It pointed out that the European Commission lacked the legal tools and powers to force EU member states to build an integrated high-speed rail network.[57] Even on its high-speed lines, the maximum speeds (300 kph) are never reached in practice: Of the lines audited, trains ran on average at only around 45 percent of the line's design speed and only two lines operated at an average speed above 200 kph, and none above 250 kph.[58]

Sector-level data provides a broad snapshot of production and export changes in the high-speed rail segment—but it obviously also includes other rail segments. While not specific to the high-speed rail segment, changes in the broader sector still reflect China's growth as the world's largest producer and market. In 2000, EU rail sector production was more than double the next-highest producer (the United States) and more than three times Chinese production (see figure 1).[59] But as China ramped up its rail and high-speed rail system and required domestic production, Chinese production rapidly increased and overtook EU production in 2009. In 2017, Chinese production was nearly twice that of EU production (and nearly 6 times as large as U.S. production).

**Figure 1: Rail supply industry production (locomotives and rolling stock, major global economies active in the sector, fixed 2017 ex rates).**[60]



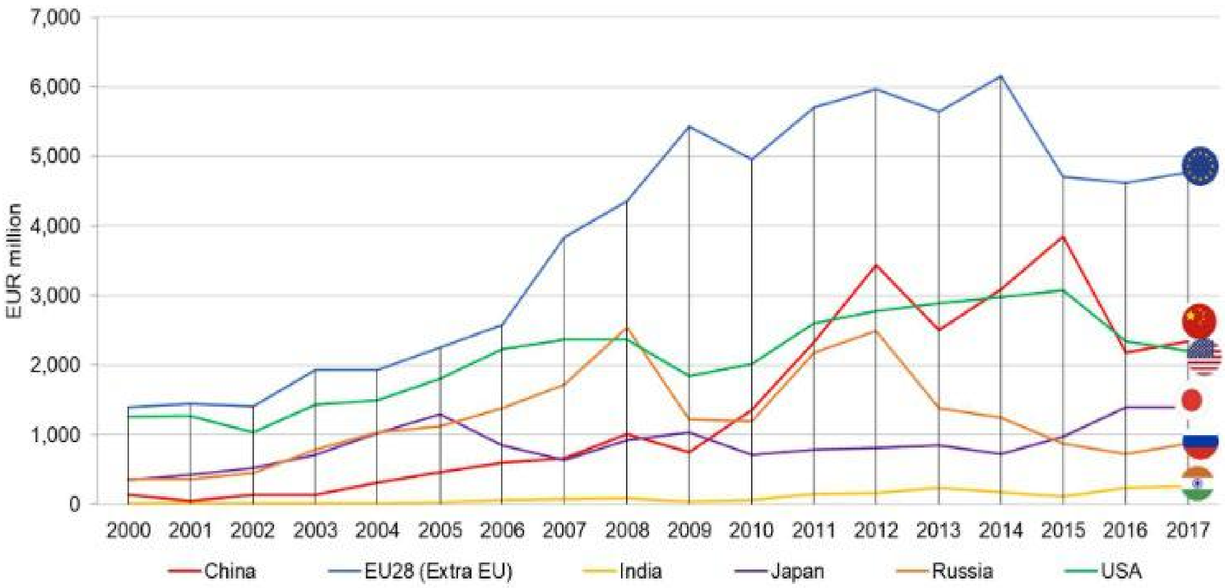

## Export Share

While China has only recently started competing for, and initiating, high-speed rail projects around the world, its and CRRC's ambitions are clear in that they plan to both directly compete for as many future high-speed rail projects as possible and build market share in other rail segments as a way to gain a foothold in the high-speed segment (see annex 2 for an analysis of CRRC's efforts to access and build market share in Europe).

The Chinese rail sector's impact on the broader rail market is indicative of its central role in the global market and what it no doubts would like to achieve in the global high-speed rail segment. Exports from China barely registered in 2000 but increased to around €2.1 billion in 2017 (see figure 2). The EU retained its position as the world's largest exporter over this time, with exports growing from around €1.4 billion in 2000 to nearly €4.8 billion in 2017. However, after a few years (2012 to 2014) of near €6 billion in exports, China's exports decreased to around €4.8 billion from 2015 to 2017. Meanwhile, rail exports from Japan also increased, but by much less, from around €300 million in 2000 to €1.3 billion in 2017.

China became a net exporter of rail products in 2010, and while it is still behind U.S., European, and Japanese firms in terms of export intensity (ratio of imports/exports), it still plays a growing role in global markets, especially in developing countries. China's growing production capabilities are also reflected in EU imports of rail products from China, which more than doubled from €101 million in 2011 to €212 million in 2017.[61] Indicative of shrinking rail market access in China, EU exports of locomotives and rolling stock to China decreased from €865 million in 2011 to €505 million in 2017.

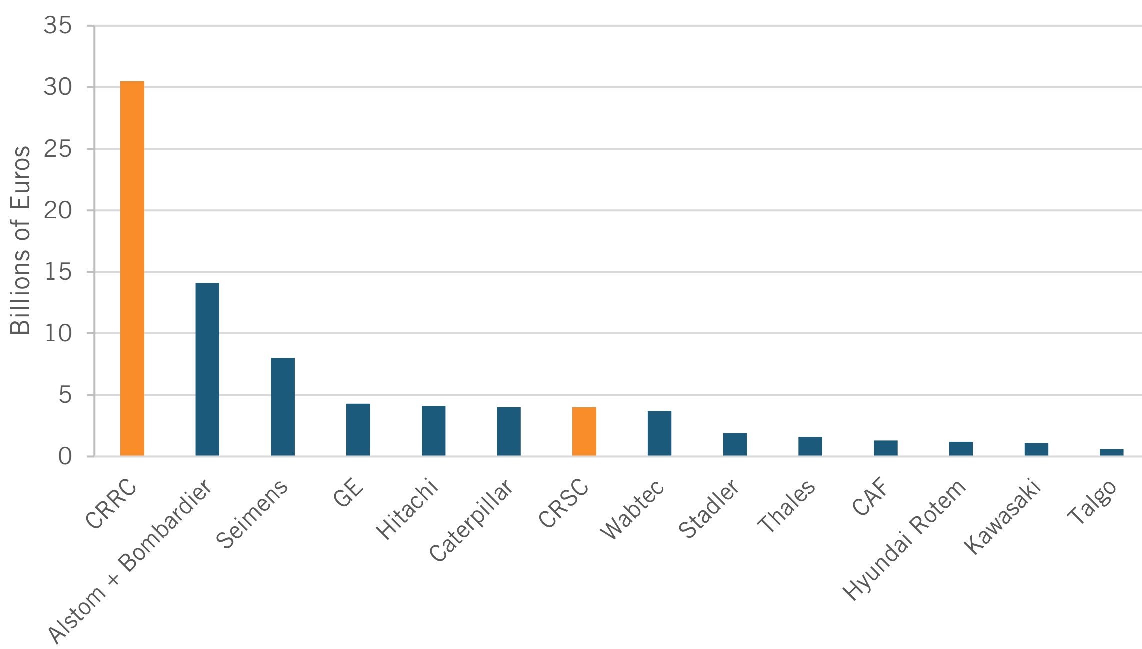
**Figure 2: Rail supply industry exports (locomotives and rolling stock)[62]**




## Leading High-Speed Rail Firms

CRRC is clearly the largest firm in the global locomotive and rolling stock market. Alstom is CRRC's most direct, pure-rail competitor in the global market. Even Alstom's and Bombardier's (which Alstom acquired) combined 2017 revenue still pales in comparison to CRRC's. Besides these two firms, the other major firms involved in high-speed rail are Hitachi, Hyundai Rotem, Kawasaki, and Siemens (see figure 3). Besides CRRC, China Railway Signal & Communication Corporation (CRSC) is one of the largest rail transportation control-system providers in the world.

**Figure 3: Leading rolling stock manufacturers in 2017 by revenue of rail activities[63]**



CRRC is not only much larger than its competitors, but it also has the broadest capabilities in the rail market (see figure 4). This highlights the broad threat China's rail mercantilism poses (via CRRC) to rail firms in all segments—not just the high-speed ones—as it is able to leverage the same mercantilist tools in these segments.

**Figure 4: Position of top rolling stock manufacturers, globally, 2018[64]**

| Manufacturer | Diesel Locomotive | Electric Locomotive | Electric Multiple Units | Diesel Multiple Units | High-Speed Rail | Passenger Coaches | Freight Wagons | Signalling/ Control Systems | Turnkey/ System Integration |
|---|---|---|---|---|---|---|---|---|---|
| CRRC | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Siemens Mobility | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ |
| Alstom + Bombardier | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ |
| GE + Wabtec | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ |
| Hitachi Rail | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ |
| Trinity Rail | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ |
| Transmashholding | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ |
| Greenbrier Companies | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ |
| Stadler Rail | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| Kawasaki | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ |
| Hyundai Rotem | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ |

## Japan

Japanese firms' role in the global rail market reflects the fact that high-speed trains were pioneered in post-war Japan in the 1950s and early 1960s with the construction of the Shinkansen bullet trains. Ever since it was launched for the 1964 Olympic Games in Tokyo, the Shinkansen has remained a source of national pride in Japan. These firms and the government continue to invest in high-speed trains and rail networks. In July 2020, Central Japan Railway introduced the next-generation Shinkansen, the N700S, which reaches a maximum speed of 300 kph.[65] Indicative of the development challenges involved in high-speed rail, it is the first fully remodeled bullet train in 13 years. In 2019, Japan started testing the ALFA-X version of the Shinkansen train, which can run at speeds up to 360 kph, with plans to bring it into service after 2030.[66]

Hitachi and Kawasaki Heavy Industries are two of the main manufacturers of Shinkansen trains, which are thus the basis for both of their exports and international projects. For example, Taiwan's high-speed rail network uses both Kawasaki and Hitachi trains, while a range of lines in the United Kingdom use Hitachi's Shinkansen technology. Kawasaki's exports in China are likewise based on Shinkansen technology (see the annex case study).

Hitachi's competitive position and recent strategic decisions are a useful reference when considering CRRC's impact on the high-speed rail sector. Hitachi was once floated as a firm that might take over Bombardier's rail assets.[67] Although Hitachi never launched a bid, its relative size explains why the acquisition could have helped it compete. As figure 3 shows, Hitachi is considerably smaller than its main rivals—its 2017 revenues of $4.1 billion were one-quarter of those of the merged Alstom/Bombardier and only 13 percent of CRRC's.

Hitachi has instead sought to partner with larger firms to compensate for its lack of scale. In 2010, a Bombardier and Hitachi JV won a contract to produce 50 high-speed trains (the ETR 1000, Europe's fastest train) as part of a €1.5 billion deal with Italy's largest operator, Trenitalia. Subsequent deals in Spain and Italy brought the JV's total production to 87 high-speed trains.[68] They also submitted a joint bid to produce train cars for the United Kingdom's HS2 project.[69] However, the Alstom-Bombardier merger reduced the need for another partner such as Hitachi in the future.[70]

### Europe

Europe's high-speed rail firms—especially Alstom and Siemens—are global leaders in many parts of the global rail and high-speed rail markets due to their innovation, skilled workforces, and ability to deliver integrated transport projects. There are also other smaller high-speed rail firms such as Stadler (Swiss), CAF (Spanish), and Talgo (Spanish).[71]

European firms benefit from the single European railway area, which provides common standards and regulations that they're often best placed to meet.[72] The EU's high-speed rail network has doubled in length since 2003; and by the end of 2017, it had over 9,100 kilometers, with plans to triple the length of its network by 2030.[73] However, its network faces some key issues, namely, ensuring trains actually run at maximum speed and integrating its high-speed lines with other forms of transport.[74] Another key strength is the well-established supply chain and the close collaboration between different segments and actors on the development of advanced products and solutions, such as the European Rail Traffic Management System (ERTMS).

These leading high-speed rail providers in the global market also support a much larger ecosystem of component suppliers that equip light, metro, and slower-speed passenger and freight trains. The United States and the EU are home to many of these firms. For example, in 2018, there were around 1,831 companies in the EU involved in manufacturing railway locomotives and rolling stock, including 541 in the United Kingdom, 369 in Germany, 196 in Poland, 135 in Italy, 99 in France, 98 in Spain, 72 in the Czech Republic, 47 in Romania, 46 in Hungary, and 38 in Sweden.[75] But this only provides a partial snapshot, as it doesn't take into account the hundreds of other EU firms that are also involved in signaling and electrification and rail infrastructure.[76]

European policymakers need to realize that while the EU's regional standards act as a barrier to CRRC and other Chinese rail firms, these barriers are not insurmountable and these firms are strategically working toward acquiring and developing the standards and technical references to achieve greater market share. For example, firms need to meet the Technical Standard for Interoperability (TSI) to bid on European rail projects. As of 2019, CRRC reportedly did not have a TSI-compliant high-speed platform.[77] However, CRRC and other Chinese firms are no doubt working toward meeting the EU's TSI so they can compete for a broader range of projects. CRRC has a factory in China that claims to operate to some TSI standards.[78] CRRC and other EU- and China-based rail R&D centers are also working toward these standards.[79]

## United States

The United States still has considerable interests at stake in the global high-speed and broader rail markets, despite it not being home to a leading high-speed rail firm.[80] As such, China's competitors for high-speed rail projects in the United States and elsewhere have been largely European and Japanese rail companies. However, the United States remains both a major general rail producer and exporter, and potential market for high-speed rail. As figure 1 shows, U.S. rail industry production only increased from around €8 billion in 2000 to just over €10 billion in 2017, while according to figure 2, rail exports increased from around €1.2 billon to €2.1 billion over this same time.[81]

Alstom, Bombardier, Kawasaki, and Siemens have all set up local production sites that, together with U.S. specialized and general train component and service suppliers, form the supplier base for high-speed rail and the broader rail sector in the United States. For example, Siemens is one of only a few firms to make train bogies in the United States, as its Mobility's factory in Sacramento, California, manufactures locomotives, railcars, and trams.[82] Hitachi has a rail factory in Miami, Florida, that supports more than 50 subcontractors and suppliers.[83] Kawasaki has operated a rail car manufacturing factory in Lincoln, Nebraska, since 2002.[84] In terms of U.S. firms, large diversified industrial companies such as GE, Caterpillar, and Wabtec are the fourth-, sixth-, and eighth-largest rail rolling stock manufacturers in the world, respectively (see figure 3). In addition, more than 750 companies in at least 39 U.S. states make components for transit, passenger, and high-speed trains and associated rail products.

The U.S. rail sector supplier base benefits from foreign investment and R&D from these foreign (non-Chinese) firms. As is typical in high-speed rail projects, the leading high-speed firms lead consortiums to bid on large rail projects that also include, or need to draw on, local suppliers and products. Siemens is the leading firm in the consortium for the new West Palm Beach/Ft. Lauderdale-to-Miami and Los Angeles-to-Las Vegas high-speed rail projects, while Kawasaki is the lead provider for the Houston-to-Dallas project.[85] Meanwhile, Alstom is leading a consortium to assemble 28 new sets of high-speed trainsets for Amtrak's upgraded Northeast Corridor service at factories in New York State, with 95 percent of the content produced in the United States.[86] U.S. firm Transitair Systems LLC (TTA) Systems (based in Hornell, New York), a subcontractor for Alstom, is working to build tilting bogies as part of an order for 392 high-speed rail cars.[87] In line with this, both Amtrak and Alstom hope this project will support the growth of an American supply chain for high-speed rail equipment, as the absence of such a supply network raised the costs and limited design choices for the original Acela project in 2000 (which was led by a joint Alstom-Bombardier consortium). Amtrak and Alstom officials blamed a 2005 disruption in Acela services (from April to July, due to cracks in many trains' brake rotors), in part, on Acela's reliance on a narrow, specialized supplier base.[88]

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U.S. firms also produce specialized parts for high-speed train systems, such as signaling and train controls (Wabtec), specialized technology for inspecting high-speed wheels (Waygate Technologies), and others.[89] For example, Wabtec provides specialized high-speed rail components (such as the pantograph) and a broad range of other components and services used for both high-speed and light and metro rail systems, including air conditioning, windows, doors, and maintenance and cloud-based services.[90] Wabtec is the product of a several rail-related mergers and acquisitions involving well-known U.S. industrial firms. It was initially formed by the merger of the Westinghouse Air Brake Company and Motive Power Industries Corporation in 1999. In 2019, Wabtec merged with General Electric (GE) Transportation, combining its broad range of freight, transit, and electronics products with GE Transportation's equipment, services, and digital solutions in the locomotive, mining, marine, stationary power, and drilling industries.[91] Indicative of Wabtec's position and how it plays a role in broader rail projects, in August 2020, Virgin Trains awarded Wabtec a $120 million contract to provide signaling and train control systems along some of its high-speed Miami-to-Orlando lines (which use trainsets from Siemens).[92]

## CHINA'S MERCANTILIST TOOLBOX FOR HIGH-SPEED RAIL

China has used an extensive and coordinated set of mercantilist tools to gain high-speed rail technology and market share. It refined and ratcheted up the restrictiveness of these tools over time as its firms became larger and more competitive. This section analyzes China's use of these tools: foreign technology transfer for market access (including a case study on Kawasaki Heavy Industries in China); massive financial support for domestic high-speed rail firms; discriminatory management of China's massive domestic high-speed rail market; squeezing out foreign firms and products while creating and supporting local ones (including a case study on "hidden" market barriers in China's transit market); and creating a monopolist national champion (CRRC). Consistent with China's approach to other strategic technology sectors, this section's analysis of these tools shows that China's innovation mercantilist playbook is in fact quite simple:

1. Identify a technology/industry as a key national goal.
2. Use access to the giant and monopolistic Chinese market as a weapon to force foreign companies to engage in JVs and compel the transfer of foreign technology to Chinese firms.
3. Use a variety of means, including direct subsidies, low-interest loans, tax breaks, forced mergers, foreign acquisitions (see annex 3), discriminatory public procurement, and other incentives to accelerate Chinese firms' technological and competitive capabilities.
4. Once Chinese firms have mastered foreign technology and gained domestic market dominance, finance "going out" (i.e., exporting to foreign markets) on the basis of a protected and subsidized domestic market and massive export subsidies.

China's strategic economic, trade, and innovation policy prioritizes high-speed rail technology. Indicative of this, China budgeted $549 billion in its 13th Five-Year Plan (2016–2020) to expand and upgrade the country's rail system, with most of the money earmarked for high-speed trains. High-speed rail is not only part of the central government's five-year national plan, but also various associated strategies, such as the Made in China 2025 plan, the Belt and Road Initiative, the China High Speed Train Independent Innovation Joint Action Plan, and other railway-specific schemes.[93] China's railway strategy, which was revised in 2008 and 2016, looks up to 15 years ahead and is complemented by its own five-year plans.[94] Hundreds of additional plans continue to be issued at lower levels of government to pursue these goals. For example, the

Hebei Province's 13th Five-Year Plan includes a sectoral plan for rail transit industry development. At the next level down, key projects are listed at the city level, such as Tangshan's focus on high-speed passenger cars.[95] As detailed in this report, there are plenty of opportunities for Chinese government officials to informally require technology transfers and provide central government deniability.

China's high-speed rail strategy has evolved over time as the country has moved increasingly toward mercantilism. In the 1980s and 1990s, the government focused on incremental domestic innovation to develop indigenous electric multiple units (or "electronic motor units" (EMUs)), which involve multiple self-propelled carriages, not separate locomotives.[96] For example, China established a specialized technology group to develop and deploy technology for the Beijing-Shanghai high-speed rail line.[97]

But the Chinese government realized that Chinese firms did not possess the needed know-how to do this. So in addition to ongoing R&D, in the mid-1990s, China's former Ministry of Railways (MOR) decided to develop high-speed EMUs based on "learning" from foreign technologies, namely, from a leased train from Swedish firm ADTranz, which ran on a line between Guangzhou and Shenzhen.[98] However, because of the rising costs of maintenance and increasing technological deficiencies, China chose not to pursue broader deployment of this train technology. Then, from 1999 to 2001, MOR and local firms worked to develop indigenous EMU prototypes (presumably based on reverse engineering the ADTranz), but due to technological deficiencies, none made it to mass production.[99] The exception was the DJJ1 "Blue Arrow" high-speed EMU (of which eight were manufactured in 2000), which took over the Guangzhou-Shenzhen line.

After the Blue Arrow, in 2001, MOR planned to develop a more-advanced high-speed EMU prototype—"the Star of China," which could reach a top trial speed of 321 kph—to challenge foreign rail technology.[100] China claims that the China Star was a home-grown high-speed system developed by state-controlled manufacturers using only Chinese IP.[101] However, the train suffered from several problems. Its repair rate was higher than the international standard and it experienced serious overheating-bearing issues at top speeds.[102] MOR once again realized that China's domestic technology was still not good enough, so less than two years later, MOR stated that the core technology was "immature," and the China Star was thus quietly shunted into a siding.[103] After a prolonged period of extensive forced technology transfers, China debuted the first "Chinese-standard" 400-kph bullet train—the "Fuxing"—in 2016, which it claims uses entirely Chinese technology.[104]

## Forced Technology Transfer for Market Access

Forced technology transfers were central to the development of China's high-speed rail sector—and they continue to be to this day. See appendix 1 for a detailed case study of Kawasaki's experience with forced technology transfers in China.

During the 2000s, MOR considered going down the same route as Taiwan, whose high-speed rail network is based on Japanese bullet trains.[105] However, China did not just want a high-speed rail system, it wanted its own high-speed rail industry—and massive government intervention to build out a massive domestic high-speed rail system was the means by which it could get it. Contracting with a company to simply sell it rolling stock was not going to help MOR achieve that goal. As Xianfang Ren, chief China economist at IHS Global Insight, stated, "If China chose one system, that would [have meant] it rendered control of the entire railway system to one foreign country."[106]

So after almost a decade of unsuccessful attempts to develop indigenous high-speed rail technology, in 2003, then-MOR Minister Liu Zhijun decided on a "technology transfer for market access" strategy in which China would make the sale of foreign high-speed rail technology contingent on forming JVs and sharing technology with Chinese producers.[107] Following this, the Central Committee of the Communist Party of China and China's State Council promulgated a strategy that acknowledged as much in articulating an "overall policy of 'introducing advanced technology, jointly designing and producing, and building Chinese brands.'"[108]

In line with this, in 2004, MOR Minister Liu Zhijun launched 3 tenders to make some 200 high-speed trains, with each one stipulating that foreign companies had to collaborate with domestic partners and transfer key technologies to achieve localization.[109] MOR assigned two leading SOEs—China South Locomotive & Rolling Stock Corporation (CSR) and China Northern Locomotive & Rolling Stock Industry Corporation (CNR), which later merged to become CRRC—to localize production. For example, the key high-speed rail JVs were Bombardier-Sifang (a CSR subsidiary), Kawasaki-Sifang (CSR), Siemens-Tangshan (a CNR subsidiary), and Alstom-Changchun (CNR). Within three years, Chinese firms started producing high-speed trains based on the foreign technology.

Each tender included two key conditions: (1) to win, the bidder had to transfer technology to China; and (2) the final products had to be marketed under the Chinese SOE rail car brand. Chinese firms not only gained complex and sophisticated capabilities very quickly on the basis of billions of dollars of R&D and engineering of foreign firms, but they also violated licensing agreements whereby they committed to only use the technology domestically, and not for exports. Chinese firms are now selling their illegal clones back into foreign markets in competition with the companies from which they coerced the technology.

Technology transfer contracts typically consist of four components: (1) the joint design of train modes based on foreign technology; (2) access to train blueprints; (3) instructions on manufacturing processes; and (4) training of engineers.[110] Chinese engineers are taught the "hows" of building components and trains a certain way.[111] They therefore must reverse engineer foreign technology if they wish to develop new variations. Chinese firms work with local universities and other research institutions to do this. China has also organized its government laboratories and universities to facilitate this forced tech transfer. MOR and the Ministry of Science and Technology (MOST) have consolidated 11 research institutes, 25 universities, 51 national laboratories and engineering research centers, and the 2 leading state-owned firms (CSR and CNR) and their subsidiaries to participate in these projects.[112] From 2008 to 2010, the National Natural Science Foundation of China sponsored 55 high-speed-rail-related R&D projects, of which 33 were dedicated to absorbing imported technologies and developing new technologies in accordance with China's goal of substituting foreign sales and IP.[113] A lot of this research went well beyond the typical innovation process in that local firms paid for some foreign patents and drew inspiration from others and used further research to create new inventions.

Bombardier, Alstom, Siemens, and Kawasaki all submitted bids for sales and tech transfer, even though they realized that their JV partners would likely become their rivals outside China.[114] All companies, except Siemens, were awarded part of the initial $1.4 billion in contracts, with the

Japanese consortium winning the largest portion (around $800 million) to deliver high-speed trains (detailed in the annex 1 case study on Kawasaki). The firms could fully manufacture the first batch of trains for these contracts overseas while training MOR engineers on their technologies. They would supply full kits—known as a "knock-down kits"—from overseas to be assembled in China to further train MOR engineers and staff. Finally, the contracts required foreign firms to partner with key suppliers to transfer component technologies for their manufacturing.[115]

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For example, Alstom's JV was chosen to supply 60 regional trains, 180 locomotives, and other equipment in a contract worth over $1.4 billion.[116] Alstom initially planned to provide three full imported trainsets, then six completely knocked down trainsets with 100 percent imported equipment to be assembled in China, and finally, 51 domestic trainsets, with 65 percent locally made content.[117] However, MOR subsequently skipped the use of the knocked down trainsets, instead requiring four of them be made domestically. Alstom provided 10 key technologies, trained over 500 staff, provided hundreds of hours of expert advice per month, and transferred over 25,000 relevant documents. It also supported its JV partner in selecting and developing Chinese component suppliers. Alstom's own documents outline how it had to localize the sourcing of an increasing range of key components as part of its trains, moving from interior components to the battery and motor and finally to the traction motor, brakes, gear box, and other complex items.[118]

Alstom's experience in China has since been rocky. China's then MOR decided to operate the trains from the initial contract at 250 kph (instead of the recommended 200 kph) and did not do the recommended maintenance, leading to technical issues. In 2011, after former MOR Minister Liu Zhijun was replaced, MOR reduced those speeds to 200 kph. Ultimately, China did not sell any of those trains outside of China. Since then, Alstom has been effectively shut out of the high-speed rail market in China. In 2012, a presentation by Laurent Jarsale (Alstom's vice president for high-speed rail products) made Alstom's position clear, as thereafter, it refused to transfer technology for very-high-speed trains.[119] Alstom does maintain ongoing JVs in China focused on the metro rail, components, and signaling markets.

These forced foreign technology transfers helped China catch up quickly and allowed the country to move to the next stage of industrial development and ratchet up restrictions to force out foreign firms and their products. Indicative of this, by 2010, executives at foreign high-speed rail firms estimated that roughly 90 percent of the high-speed technology used in China was derived from partnerships or equipment developed by foreign companies.[120]

So why did foreign companies do enter China and hand over their technology? One reason is they failed to anticipate China catching up as quickly as it did. Executives from Siemens and Kawasaki, for example, did not expect Chinese companies to be a competitive threat for many years, maybe decades.[121] A *Financial Times* article quotes a Japanese executive familiar with the

2004 deal saying that although members of the consortium realized the deal could help give China a start in the industry, they "could not imagine" the catch-up would be so fast.[122] As academics Dan Prud'homme and Max von Zedtwitz, "This highlights the dangers of collaborating with Chinese companies that are supported by the state, learn quickly, upgrade their technological capabilities, and have an uncanny ability to quickly scale up operations."[123] This is not to mention dealing with a nation and its enterprises that have absolutely no compunction whatsoever of pilfering foreign technology and IP, often in direct contravention to the nation's WTO commitments.

But the real reason the firms did this was because they felt they had no real choice. Executives from Siemens and Kawasaki were both eager for contracts and feared that if they didn't do deals with China, their competitors would. China had shown its willingness to cut out foreign firms from that massive Chinese market if they didn't "play ball" (form JVs and transfer technology) in a number of other industries, including telecommunications equipment.[124] Top management was not blind. Foreign rail companies were forced to enter JVs and transfer technology as a condition of market access. And while it makes sense that China would want to do this, given how far behind they were in high-speed rail, this still constituted a violation of WTO rules (which China agreed to in joining the WTO in 2001).[125] Since the WTO prohibits these types of deals, China hides them in informal agreements Chinese government officials and SOEs force on foreign firms (see the case study on hidden market barriers in China's metro train market). The agreements likely involve other WTO-inconsistent clauses, such as export-performance and local-content requirements, as conditions for investment approval or to obtain a Chinese bank loan.[126]

Forced technology transfers remain a centerpiece of China's broader rail and high-speed rail development strategy to this day. For example, China's ongoing requirement for 100 percent Chinese-owned technology in many procurement contracts, combined with foreign firms having to engage with majority-Chinese owned JVs in order to submit a bid, amounts to a de facto mandate to transfer technology to local partners. Foreign firms continue to capitulate because they have no choice—they either give up their technology or lose out to other competitors in the growing Chinese market.[127] The massive purchase of rolling stock, signal systems, and related equipment is something no foreign rail producer can afford to ignore. Looking at the growth of the Chinese market, foreign firms can hardly resist such a Hobson's choice, knowing that if they do resist, China will award the contract to a competitor that is hungrier for short-term sales—and China still gets the technology. In essence, these firms face a monopsonistic buyer as the Chinese government, rather than private companies operating rail systems, dictates contracts and purchases.

**Forced technology transfers remain a centerpiece of China's broader rail and high-speed rail development strategy to this day.**

However, China's use of forced technology transfers is a double-edged sword as it will force CRRC (and other firms) to reveal details of its technology—even possibly that it made limited changes to technology transferred to it by its foreign partners—when it seeks to protect its IP in other countries.[128] This raises a central point of tension and conflict between Chinese and foreign rail firms—China's high-speed rail sector has faced repeated and ongoing claims of patent infringement, especially by Japanese firms. China has responded to claims of IP theft related to high-speed rail by saying that they've simply surpassed their designs and continued to innovate further.[129] Despite its repeated claims over the last decade that its high-speed rail technology is homegrown, in 2010, media reports state that the then MOR organized a team of lawyers and officials to investigate how vulnerable Chinese rail companies would be to IP lawsuits when they start selling in international markets.[130] Indicative of this, in 2011, Tadaharu Ohashi (former chairman of Kawasaki Heavy Industries ) told Japan's *Asahi Shimbun* newspaper that his company would launch a lawsuit if China violated its IP rights. "The Chinese government promised it would use the technology only inside China."[131] Despite these concerns and threats, there have not been any reported legal cases involving foreign firms challenging Chinese firms seeking to apply for patents in their home or third-country markets.

## Massive Financial Support for Domestic High-Speed Rail Firms

Forced tech transfer is not enough to ensure Chinese firms are competitive; China also uses massive subsidies (most of them WTO-illegal) to build its domestic market and firms. Indeed, China's firms competing in advanced-technology industries depend on a vast array of subsidies. Preferential debt financing and other direct and indirect financial subsidies are critical to the domestic and global success of China's rail sector, especially its high-speed rail firms. For example, Chinese rail firms have taken on tremendous amounts of state-supported debt. CRRC's debt surged over sevenfold from $70 billion in 2005 to over $558 billion in 2017, much more than many countries' national debt.[132]

Thanks to the uneven playing field these financial subsidies create, Chinese rail firms are not constrained by the usual concerns for profits that firms in other nations are under. An unnamed senior executive at a foreign rail company said in an interview: "Alstom, Kawasaki Heavy Industries, and Siemens are not banks and do not have the political influence or the full weight and money of the state behind them in the way the Chinese rail companies do."[133]

CRRC is the key beneficiary of China's financial largess. It is quite the understatement for CRRC to state (as it did in a financial report) that a reduction in government subsidies would have a "definite negative impact on the company's business results and financial position."[134] In terms of direct financial support, CRRC is one of the most heavily subsidized companies in China. In its listing announcement on the Shanghai Stock Exchange, CRRC noted that it received $194 million in government subsidies in 2014 and an additional $268.7 million in 2015.[135] CRRC's English language annual reports show that it received approximately 243 million RMB (about $34 million) in "government grants" in 2018 and 994 RMB (about $140 million) in 2017. CRRC also receive extensive R&D subsidies. As 1 of the 10 sectors China targets under Made in China 2025 strategy, firms involved in advanced rail technology also receive preferential R&D support in the form of subsidies and tax incentives. China also reduced the income tax rate for high-tech industries from 25 percent to 15 percent and raised the rate of additional deductions of R&D expenses from 50 percent to 75 percent.[136]

**Thanks to financial subsidies, Chinese rail firms are not constrained by the usual concerns for profits that firms in other nations are under.**

CRRC also receives direct financial backing from Beijing worth orders of magnitude more than the "government grants" listed in its English language annual reports. Radarlock's 2019 report

“CRRC and Beijing’s Dash for Global Rolling Stock Dominance” details how Chinese financial statements list far more.[137] CRRC’s Chinese financial documents report more than 5.4 billion RMB (almost $800 million) in direct subsidies since 2015, with 1.37 billion RMB (approximately $191 million) in 2018 alone.[138] Even this likely represents an incomplete picture of direct government support, as company financial documents also acknowledge government subsidy contributions to “non-operating income,” “other receivables,” and “other cash received relevant to business activities.”[139]

It is difficult to estimate the full picture of Chinese government support, considering the indirect subsidies provided via tax cuts for R&D for firms in related strategic industries, the limited incentive to publicly report government financial support, and the ease with which China can direct unreported funds to entities it owns and controls. For example, CRRC leads China’s drive for innovation in high-speed rail and runs government-supported national engineering laboratories. In 2017, CRRC was designated as the lead on the National High-Speed Train Technology Innovation Center. The company benefits from significant state support for R&D. Since 2016, it has led the Special Project in Advanced Rail Transit, through which it won R&D projects worth at least 433 million RMB (around $68 million) in 2016; 44.21 million RMB (around $6.8 million) in 2017; and 85.27 million RMB (around $13.1 million) in 2018—more funding than any other entity involved in China’s National Key R&D program.[140]

Chinese high-speed rail firms also benefit from the massive amounts of debt involved in building and supporting China’s high-speed rail services, many of which are unprofitable.[141] At the end of September 2019, CSRG—which owns the operators of all of China’s high-speed, as well as normal, rail lines—had $787 billion in debt representing 65 percent of total assets.[142] CSRG’s 5.48 trillion RMB (around $846.5 billion) in liabilities at the end of 2019 is equivalent to 5.5 percent of China’s annual gross domestic product (GDP). In 2019, CSRG’s profit margin was 0.2 percent.[143] CSRG’s reliance on debt is reinforced by most high-speed rail lines in China running at a loss. CSRG reported that more than 60 percent of high-speed rail operators lost a minimum of $100 million each in 2018 and continued losing money into the first half of 2019. The Chengdu line was the least profitable, losing $1.8 billion in 2018. Other operators in Shenyang and Harbin each reported losing more than $1.5 billion in 2018.[144]

Although the investment payback period for high-speed rail lines is long term, these lines are enormously unprofitable. However, besides key lines between major cities (such as Beijing, Shanghai, and Guangzhou), most other lines would barely or not be profitable.[145] The Beijing-Shanghai line (which opened in June 2011 and cost $29 billion) took five years to turn a profit.[146] China appears willing to keep making huge investments and providing financial support to develop and operate unprofitable high-speed rail lines, which obviously benefits CRRC. China’s central government injected 100 billion RMB (around $15.5 billion) of additional capital into CSRG in 2020.[147] Given that most new high-speed rail lines will be built in the less populated and developed central and western regions of China, the chances these lines will be profitable for the foreseeable future are hard to see.[148] Hence, the reliance on government subsidies and debt is only going to continue.

## Discriminatory Procurement

The state’s complete control of its massive national market—via discriminatory procurement processes that favor SOEs—is one of the biggest tools in China’s innovation mercantilist toolbox. Not only does this give the government significant leverage for forced technology transfer, but once Chinese firms can compete with foreign firms, it gives the government the ability to create a protected market, wherein local firms are assured significant and stable revenues without having to engage in fair competition and genuine innovation. Considering discriminatory public procurement criteria alongside other mercantilist policies, especially forced technology transfers, amounts to an ongoing de facto mandate to transfer technology to local partners. This section analyzes China's extensive use of public procurement to further its mercantilist strategy for high-speed rail.

China controls one of the most restricted procurement markets in the world.[149] It has used its dual control of its state-owned firms and procurement market to protect and support Chinese firms and products. There have been cases wherein CRRC started production before the tender was even issued. By the time the contract was signed, CRRC already had trains ready for delivery. This is indicative of how unfair the Chinese procurement market is, given the state is on both sides of a public procurement project. Because of its huge market size, this is hugely problematic for foreign rail firms. The situation in China is further complicated by the "gray zone" of contracts issued by state-owned firms. China's government statistics understate the size of its procurement market, as they do not take purchases made by China's large SOEs and other government-linked institutions into account.

China is one of the largest public procurement markets in the world. However, indicative of the challenge of entering and competing in China, estimates of its exact size vary significantly, from 5 to 20 percent of China's GDP. Chinese government statistics claim it is around $224 billion, while the EU Chamber of Commerce in China estimates it is four-times as large.[150] Whatever its specific size, it has grown rapidly and is worth hundreds of billions of dollars a year.[151] These restrictions represent a de facto extension of China's Buy Chinese policy to a substantial part of tenders issues by SOEs.[152]

China is not bound by any international rules or best practices relating to public procurement. Despite repeated promises to do so, China has yet to join the WTO's Government Procurement Agreement (GPA), and remains unwilling to relax restrictions on SOE procurement. Even when China enacted reforms to improve public procurement processes, it excluded certain projects, including China's high-speed rail network, from those requirements such that all work could still be directed to Chinese firms.[153] Furthermore, as the European Commission notes, the existence of procurement legislation and implementing guidelines, while designed to improve the effectiveness of public procurement in China, hides the fact that the allocation of public contracts under these rules is not open, competitive, or based on market rules.[154]

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Just to submit a bid, China requires rail firms to hold a license to operate and compete for public procurement contracts. But to get a license, foreign firms must set up a JV with a Chinese partner. Foreign firms report that tenders are only open to local companies or JVs in which the Chinese partner has no less than 50 percent of the JV's shares.[155] Even then, only a limited number of domestic companies are qualified to be bidders or primary contractors on rail projects, which means foreign firms can only ever be minor providers through local JVs.[156] In some instances, China's procurement rules prevent Sino-foreign JVs from obtaining a qualification to bid.[157]

Bombardier's local JV appears to be the lone survivor doing any substantive production for China's high-speed rail market. Founded in 1998, Bombardier Sifang is the JV between the Canadian company and a unit of CRRC. Showing the complexity of entering and competing in China's rail market, Bombardier has a total of seven JVs and six wholly foreign owned enterprises in China that together have delivered 4,500 railway passenger cars, 580 electric locomotives, and over 2,5000 metro, monorail, and tram cars in China. It has also provided signaling and propulsion systems to 30 Chinese cities.[158] Bombardier is the rare exception in that it is the only one of the major foreign rail firms that has recently received a major contract. In 2018, Bombardier's China JV won orders for high-speed trains worth $545 million, representing one of the biggest orders it has ever received in China.[159] In addition, in January 2020, Bombardier's JV won a contract to build 160 new high-speed train cars (valued at $427 million).[160] It was the only foreign JV to win a part of this round of contracts.[161]

Bombardier seems to be the designated exception, as the general rule is that as Chinese firms become more competitive over time, China changes the procurement restrictions to squeeze out foreign firms and products. It does this by including assessment criteria for procurement contracts that explicitly exclude or disadvantage foreign firms and products. In some instances, tender invitations penalize or exclude consortiums that involve foreign JVs (which is common for large rail projects). For example, in 2014, the China Railway Group launched a tender to supply some 232 high-speed trains for a contract from which consortiums were excluded from the bidding.[162]

Procurement evaluation criteria have also been designed to grant more points to Chinese companies or JVs in which the Chinese company owns the majority of shares (versus 50-50 Sino-foreign JVs). Firms with local IP (certified by the national rail association) score more points in procurement criteria than those that use foreign technology.[163] For example, in 2015, Knorr-Bremse AG (a German manufacturer of braking systems) received tender documents from 11 Chinese cities that stipulated new bidding rules that scored down foreign-invested firms versus purely local names. It lost out on three tenders as a result.[164]

China's restrictive approach is well above and beyond the usual local content requirements involved in many countries' public procurement processes for large-scale rail projects.[165] Indicative of this is most major rail providers (e.g., Alstom, Bombardier, and Siemens) still compete in many third-country markets despite local content and production requirements. The approach simply reflects the lack of reciprocity, given no U.S., European, or Japanese firms can enter the Chinese procurement market the way CRRC and others have entered the American and EU procurement markets for rail products and projects (see annex 2 for a detailed assessment of Chinese rail firms' success in Europe).

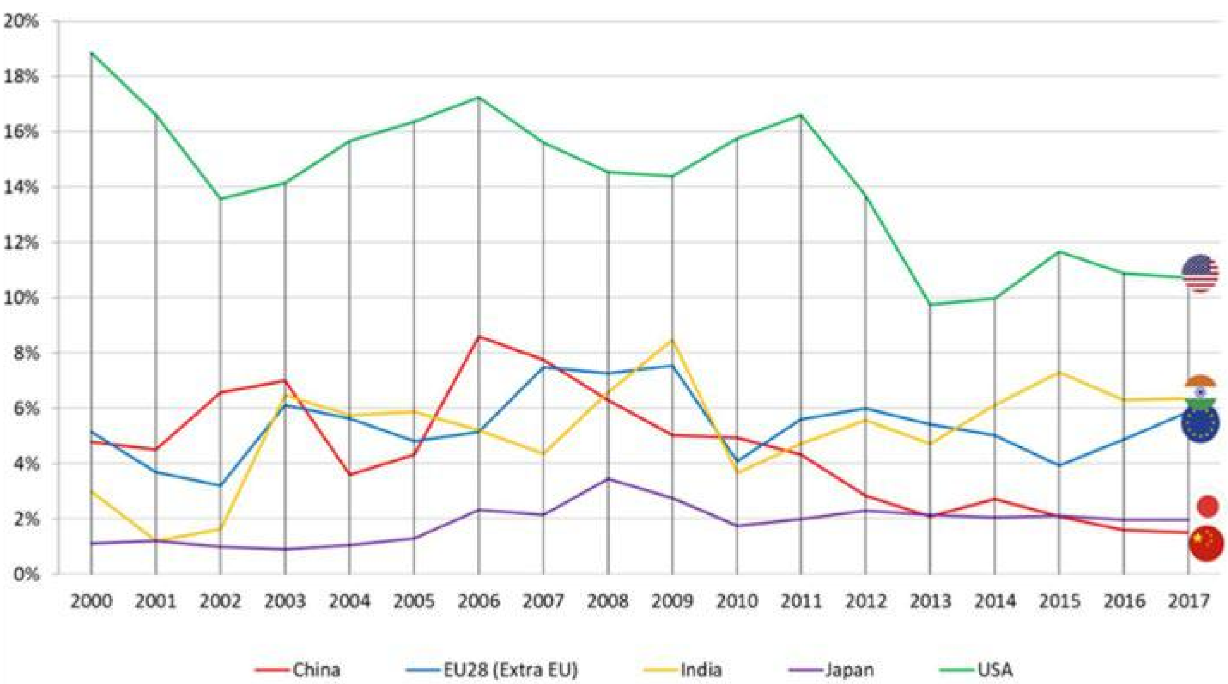
Despite announcements by China's State Council to the contrary, procurement discrimination in the rail market and other industries persists (in terms of treating foreign firms and their products fairly).[166] China has repeatedly committed to de-linking and removing indigenous innovation policies at all levels of public procurement as part of agreements with the United States (during the U.S.–China Strategic and Economic Dialogue). This includes a State Council measure that mandated local governments eliminate any remaining linkages by December 2011. In 2016, following further complaints from the United States, China's State Council had issued another similar directive. However, this never happened, which shows how China lacks any credibility in terms of abiding by trade commitments and how hard it will be to effect change in China without clear and effective enforcement and remedies for violation.[167]

## Limiting Access of Foreign Firms and Products While Creating and Supporting Local Ones

Foreign market access in China's regular and high-speed rail markets has decreased dramatically over the last 20 years. UNIFE's 2020 World Rail Market Study—the only global assessment of the sector—regards the Chinese market as having been only 17 percent accessible for the period of 2017–2019, as compared with 63 percent for the period of 2009–2011—a 70 percent decrease. This compares with an accessibility rate of 79 percent in the European market.[168] Foreign high-speed rail firms state that the market segment for completed high-speed rail trains has been effectively closed to most of them since 2010 and that the broader rail rolling stock market is largely (and increasingly) inaccessible to foreign suppliers.[169]

China has become self-sufficient and now largely excludes foreign firms and their products from this market. Indicative of this, import penetration—the value of imports divided by the value of consumption—in China dropped from 8 percent in 2006 to less than 2 percent in 2017 (see figure 5).[170] Even during earlier periods of rapid growth in the domestic market, foreign firms were still unable to export much to China. Given that many countries have local content requirements as part of rail-related public procurement projects, import penetration is never going to be large—although it does show the gap in opportunity compared with the United States, the European Union, and India.

**Figure 5: Import penetration (imports divided by consumption)[171]**




European firms are the main losers from decreasing access to China's locomotive and rolling stock market, as their exports made up 60 to 70 percent of all imports for 2014 to 2017, and

85 to 95 percent of imports of signaling and electrification goods over that same time period (see figure 6 and figure 7).[172] From 2014 to 2018, Chinese imports of rail products dropped for many European countries—by 10 percent for Italy, 11 percent for France, 12 percent for Hungary, and 22 percent for Germany. Likewise, exports from Japan and the United States dropped by 25 and 26 percent, respectively.[173]

**Figure 6: European market share of imported products in China (locomotives and rolling stock, 2014–2017)[174]**

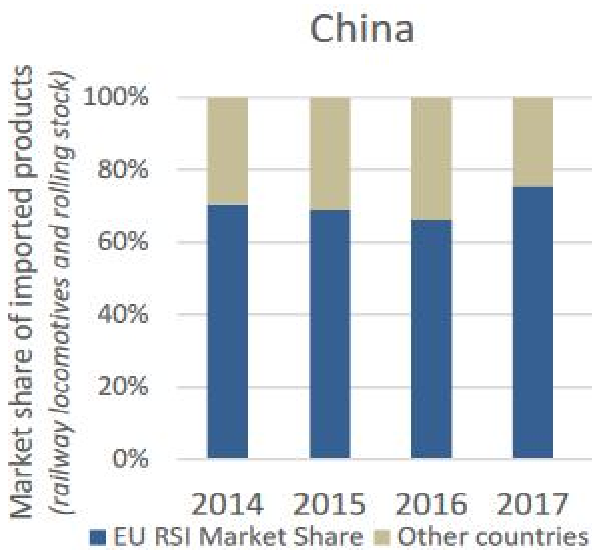
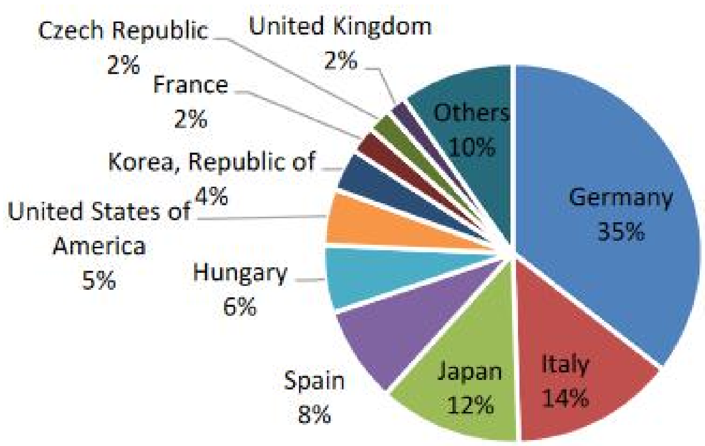



**Figure 7: China's imports of railway, rolling stock, and related components (of percent imported in 2018)[175]**




Even though imports have never represented a large part of the market, China continues to take a targeted (and punitive) approach to reducing the use of foreign firms and technology (see box 2 below). China's restrictive local content, technology, and JV ownership requirements amount to a large market access barrier and an ongoing mandate for forced technology transfer to local partners.

There's simply no question China is working to decrease foreign ownership in JVs, which are themselves becoming more problematic. Foreign rail firms are being forced to water down their shareholding in JVs. The nature of the relationships is also becoming more tenuous and litigious, with ever-more financial disagreements as local partners push for greater ownership and control.[176] While China's high (and increasing) local content requirements for public procurement in the rail sector (reaching 75 percent in some specific sectors) are similar to those used in the United States (which increased from 65 percent in 2015 to 70 percent in 2020 for public transit rolling stock), it's a false equivalence when combined with the panoply of other restrictions, China's lack of protection for foreign IP, and China's overarching goal to control rail technology.

**China's restrictive local content, technology, and JV ownership requirements amount to a large market access barrier and an ongoing mandate for forced technology transfer to local partners.**

In China, this ratcheting up of local content criteria makes foreign JVs increasingly vulnerable to being forced to hand over further technology to local firms and, eventually, being squeezed out completely.[177] China typically requires firms in JVs to prove that at least 70 percent of their supply chain is in China and at least 70 percent of equipment for any given rail project is sourced from local companies.[178] Over time, China's localization requirements have been steadily increasing, reaching 75 percent for metro rolling stock (70 percent in 2013), 50 percent for metro traction (40 percent in 2013), and 60 percent for metro signaling (55 percent in 2013).[179] Additionally, China has for many years required that 100 percent of the technology be Chinese-owned .

As with other sectors it identifies as strategic, China's ultimate goal for the high-speed rail sector is autarky. China conducts exhaustive reviews of which components are domestic versus foreign, after which it develops strategies and provides funds to local firms to create copycat replacement components that aren't foreign (see box 2). China's pursuit for autarky has only intensified with the U.S.-China trade dispute. Its government has extended its desire for self-sufficiency in the rail sector down the supply chain, targeting relatively small, specialized foreign component providers—even ones that, in some cases, have demonstrated a long-standing commitment to work in a mutually beneficial way with CRRC and other Chinese rail firms.

**Foreign rail firms in the Chinese rail market often find themselves facing explicit state-supported efforts to replace them—even those with a track record of having made a long and substantial commitment of genuine and mutually beneficial cooperation with a Chinese JV partner.**

Media reports and interviews with foreign rail firms outline the dismal trajectory for these firms and their products. Media reporting from 2016 stated that foreign firms' concern over wholly local firms increasingly being favored at the expense of foreign JVs.[180] For bids involving standard trains, China often completely forgoes open tendering and instead directly awards contracts to domestic suppliers, with foreign suppliers increasingly limited to sub-supplier positions, if anything. In 2014, media reports quoted officials from foreign firms stating that, even at that time, foreign firms still supplied many advanced components used in Chinese high-speed trains (e.g., traction, brakes, and control software).[181] But as of 2016, reports state that foreign rail firms find themselves shut out of providing these advanced components as China improves domestic capacity and promotes homegrown technology under Made in China 2025.[182] Over time, China has excluded a growing range of foreign products from procurement contracts, leaving them an ever-shrinking share of projects involving products with critical functions (wherein government authorities realize that local copycat products remain inferior).[183] While foreign firms may have a large installed base in the Chinese market (which provides a residual market for some), these products will ultimately be replaced as Chinese replacement products improve.

China directly pushes out foreign firms and products by directly supporting new local entrants in key technologies. Foreign rail firms in the Chinese rail market often find themselves facing explicit state-supported efforts to replace them—even those with a track record of having made a long and substantial commitment of genuine and mutually beneficial cooperation with a Chinese JV partner. This can involve the government ordering one or two Chinese firms to produce specific copycat products. For example, a representative from the JV between French electronics firm Thales and state firm Shanghai Electric Group (which supplies signaling systems to Chinese subway projects) stated in 2016 that it had increased from four or five signaling suppliers in the industry to nine, with another three set to be approved (given a license) by China's National Development and Reform Commission (NDRC, the influential agency in charge of China's macroeconomic planning and formulating and implementing many industrial development strategies).[184] This highlights that China isn't worried about the inefficient use of funds and R&D, or unreliable copycat products—so long as Chinese firms control the technology. The Chinese copycat firms will learn and improve over time.

## Box 2: NDRC and "Hidden" Market Barriers in China's Urban Transit Market

Foreign rail firms state that China's rail market restrictions have become more hidden over time—so as to minimize the potential for trade disputes—especially via the use of informal, indirect guidance from trade associations and state-owned firms. In 2020, Chinese government authorities used informal guidance to industry associations that effectively closed the entire urban transit market to foreign firms and products. While this does not directly relate to high-speed rail, it is indicative of how China continues to discriminate against foreign firms and products. It also shows that, if it is willing to do so for the metro train market segment, China is almost certainly using these same methods in the high-speed rail market.

China's NDRC informally released a new list—the Autonomous Recommendation List of Equipment—directly to the China Association of Metros (CAMET) for use in designing the evaluation criteria for its firms when buying products. This includes whether the supplier is local or foreign-controlled (thus excluding majority-foreign-owned JVs), whether the core technology and IP are Chinese or foreign, and whether it uses Chinese or foreign standards. NDRC did not formally publish the guidance—no doubt because it wanted to avoid scrutiny and retaliation from foreign trading partners—as doing so would have contravened the country's WTO commitments (which has happened in prior cases in which discriminatory rules were formally published). There was a complete lack of transparency about this major new trade restriction, and neither NDRC nor CAMET notified foreign firms about this new criterion (individual Chinese firms notified their foreign partners).

NDRC leverages its power over metro transit operators to force them to prioritize their efforts to promote “autonomous equipment.” In reaction to recent trade tensions, NDRC started prioritizing “industrial security” to expand support and protection for domestic products in strategic sectors.[185] This drive for autarky makes little sense given Chinese firms already dominate in key technologies in the metro transit market (i.e., around 95 percent of signaling, propulsion, and train vehicles), so China could not even use the mercantilist claim (which it uses elsewhere) that foreign firms control a key technology. This new restriction is significant, as China’s urban transit market was one of the few Chinese transportation markets that was still relatively open for foreign firms.

## Creating a Monopolist National Champion: CRRC

China’s industrial and competition policy shows that the government often lets its firms compete in the initial stage after they benefit from forced tech transfers and efforts to scale up, in part, to determine which firms are most capable. It then picks one or two national champions to favor, including with contracts, or requires a merger of competitors to create a large firm with the scale and capabilities to take on foreign competitors. For high-speed rail, China chose the latter strategy and created CRRC—a conglomerate of over 80 entities—which became the world’s largest and most diverse rail rolling stock supplier. CRRC is central to China’s high-speed and broader rail strategy.[186]

CRRC’s history reflects China’s change in strategy. In 2000, the China National Railway Locomotive & Rolling Stock Industry Corp. (as it was then known) was split into CNR and CSR to encourage competition. CNR and CSR largely targeted regional markets north and south of the Yangtze River in central China.[187] However, this competition was not always efficient, nor welcomed. In some cases, CNR and CSR competed for orders from Chinese cities by building production facilities before they’d even secured orders, a practice the central government later had to explicitly prohibit.[188] The two companies also competed against each other in foreign markets. For example, in a contract in Turkey in 2011, CNR offered $1.2 million per car as compared with CSR’s quote of $2 million per car, which forced the latter to cut its price (the order was subsequently given to a South Korean company). This scenario happened again in 2013 in Argentina.[189]

China reconsidered the split, in no small part, due to the need to improve the rail sector’s ability to compete.[190] One media report at the time of the merger stated that “the relatively limited market for high-speed trains makes one leading company per country enough.”[191] The 2015 forced merger of CNR and CSR created CRRC. While CSR and CNR used to compete against Kawasaki Heavy Industries, Bombardier, Alstom, and Siemens, as of 2015 it became “CRRC versus everyone.” That year, the combined sales of CNR and CSR totaled $31.4 billion, more than 20 times more than the railway businesses of either Hitachi or Kawasaki Heavy Industries.[192] By 2016, CRRC commanded over two-thirds of global rolling stock deliveries, taking significant market share away from the two other, now smaller, leading firms, Alstom and Siemens.[193] As of 2017, domestic demand accounted for around 91 percent of CRRC’s revenue.[194] While CRRC may have had only relatively limited global sales after it formed, its control of the vast protected domestic market gave it a 30 percent share of the global rail market.[195] As figure 3 shows, CRRC is orders of magnitude larger (in terms of revenue) than its foreign competitors.

This merger marked an inflection point in China's rail strategy as it created a huge, local champion that was dominant at home and, over time, increasingly active internationally.[196] Streamlining the structure of existing SOEs into large industrial groups facilitated the state's goal of "exerting control and implementing development policies through the networks organized around the core companies."[197] The State Council approved the merger "under the strategic goal of China's high-speed rail [to] go out" (e.g., export) and to "better optimize the resources and competitiveness of China's rail transit equipment manufacturing industry, removing internal competition and contradictions."[198] Unlike other countries, China did not have to worry about monopolistic pricing from its new champion, as the State-owned Assets Supervision and Administration Commission of the State Council (SASAC) controls CRRC.

CRRC remained reliant on forced cooperation and foreign technology transfers, which continued as part of China's policy "to acquire international renown [in the high-speed rail sector]." CRRC:

> carried out strategic cooperation with General Electric and Electro-Motive Diesel (EMD), introducing advanced foreign technology ... In the process of technology introduction, digestion, absorption, and re-innovation, CRRC has not only greatly improved its technical level and ability, but also built a new generation of vehicles with complete intellectual property rights based on the imported products ... laying a technical foundation for exporting to high-end markets.[199]

Importantly, the strategy from 2008 onward was not only of "absorption" and "indigenous technology creation," but "outward technology exploration."[200] After years of technical accumulation and knowledge acquisition, CRRC started pursing foreign acquisitions and establishing overseas R&D centers. Today, CRRC has 17 overseas R&D centers, including in Austria, South Africa, Turkey, the Czech Republic, Israel, Italy, Germany, the United Kingdom, Russia, Australia, Switzerland, Italy, and the United States (also see annex 3). Those in the United States focus on rail technology, 3D printing, new energy, data processing, sensor networks, and in-vehicle wireless network equipment.[201] This includes the rail transit, new energy, and in-vehicle networking center built with the New Jersey Institute of Technology and the University of Texas in 2012. As Huang Ying, an Economics professor at Wuchang Shouyi University in China explained, they enabled CRRC to "continuously acquire emerging technologies from the host country and to update technologies in a timely manner, and they ensure that spillovers and integration continue."[202] In the Chinese market, as Chinese firms grew, foreign firms were squeezed for technology, and over time, squeezed out. In other words, after Chinese state-owned firms "digested" foreign high-speed rail technology at home, they went overseas to do the same.[203]

## CHINA'S HIGH-SPEED RAIL MERCANTILISM GOES GLOBAL

China's efforts to develop indigenous high-speed rail technology and its champions is only part of the strategy. The country also wants to use the protected home market as a base to seize global market share—and with it, the revenues, acquisitions, and technology that come with global market share and leadership in high-speed rail. Academic Luo Qin of Guangdong University of Foreign Studies stated in his 2018 article "CRRC's Internationalization Strategy" that the goal was acquisition of strategic resources (referring chiefly to technology and data) and international markets.[204] China's ambitions are clear. Made in China 2025 includes an explicit goal for foreign sales to make up over 40 percent of China's advanced rail sector total sales and over 20 percent for the rail service sector by 2025.[205] Even if CRRC and other Chinese rail firms are only partially successful in achieving the ambitious sales targets that Chinese policymakers often set for firms in strategic sectors, the impact on the global market will still be significant.

### Use Subsidies to Gain International Market Share

The last stage in China's innovation mercantilist playbook, once firms have technology and scale, is to "go out"—to try to capture market share in other nations. And once again, the Chinese government plays a key role in this.

Indeed, CRRC's ability to access low-cost state-backed financing allows it to systemically underbid its competitors by 20 to 30 percent in public procurement bids in Europe, the United States, and elsewhere. Like its foreign competitors, CRRC has adapted to the localization requirements that are commonly mandated in many countries as part of rail procurement contracts. CRRC has established overseas manufacturing bases in Australia, India, Malaysia, South Africa, Turkey, the United States, and other countries.[206] While localizing operations comes at a price, large amounts of cheap, state-backed financing go a long way toward removing it as an equalizer between firms.

For example, between 2014 and 2017, CRRC (unbelievably) won four of the largest urban rail contracts in the United States, thanks to an unbeatable price tag. In 2014, CRRC's bid for a Massachusetts Bay Transportation Authority (MBTA) procurement contact (worth $566 million) for some 284 metro cars beat Bombardier, Kawasaki Heavy Industries, and Hyundai Rotem. CRRC's bid was more than $150 million below the next lowest bidder (Hyundai Rotem) and nearly half that of Bombardier's $1 billion bid.[207] In 2017, MBTA awarded CRRC another $277 million contract to build another 120 new cars.[208]

CRRC also invested $100 million in a factory in Chicago with the hopes of winning contracts to build subway cars and other passenger trains in America. For a contract for Chicago's metro, CRRC's Chicago subsidiary bid $1.55 million per car, compared with a bid of $1.82 million per car by Bombardier.[209] CRRC also won a $137 million contact with the Southeastern Pennsylvania Transportation Authority for 45 commuter rail cars. CRRC's bid was $47 million less than the next competitor (Hyundai Rotem). A spokesman for Hyundai (which has a local factory in Philadelphia) stated, "I cannot grasp how they are able to do it at that cost."[210] CRRC attempts at using these local factories to gain further local contracts around the United States continue. For example, in 2016, CRRC won a $178.4 million contract from the Los Angeles County Metropolitan Transportation Authority for 64 subway cars, with an option for 218 more beginning in 2021.[211]

CRRC's main advantage is it is able to offer a cheaper alternative to its rivals because it is supported by large and cheap state-backed financing, and it never had to bear the expense of researching and developing the key technologies it pilfered from others and now sells cheaply on international markets. Preferential, state-provided loans are critical to China's efforts to help Chinese rail firms go overseas and capture global market share. This is on top of the fact that China is willing to bid and provide most of the financing for higher-risk projects in developing countries, which sometimes makes it the only bidder. Dou Xin, a spokeswoman for CRRC, stated as much: "The biggest obstacle for countries that have signed deals with China is the lack of financial strength. High-speed railways and bullet trains are unimaginable [*sic*] expensive."[212]

Export financing is critical, as high-speed railway projects involve expensive construction—and the high-speed trains are just one relatively minor part. For example, the World Bank estimates that the cost of railway construction accounts for about 82 percent of total project costs.[213] Thus, rail firms need to form a broad consortium to deliver an integrated high-speed rail project. A 2013 World Bank analysis shows that China high-speed rail projects have a typical infrastructure cost of about $17 million to $21 million per km. Meanwhile, costs in Europe for projects are estimated to be around $25 million to $39 million per km. Excluding land, rolling stock, and financing costs, the costs for a similar proposed project in California were estimated to be as high as $52 million per km.[214]

Given this, the global battle to win high-speed rail contracts is as much a battle over financing as it is over train technology. It has also become a proxy for the broader competition between Japan and China for industrial supremacy and political influence in Asia. Among countries with major rail companies, Japan is the only one that offers substantial financing packages to help its rail companies win bids.[215] In October 2015, Siemens's chief executive called on the German government to provide more backing for the country's industrial exporters, noting, "We see increasingly state-backed offers from China and Japan in international competitions to which we don't really have an answer."[216] For example, in December 2015, Japan won a $15 billion bid to build a high-speed line between Mumbai and Ahmedabad in India. It secured the deal with a $12 billion loan at 0.1 percent over 50 years, with a 15-year up-front repayment moratorium. It also requires the use of core Japanese technology and research cooperation.[217]

Many of China's overseas rail infrastructure projects are not won via open tenders (such as those promoted by the World Bank or Asian Development Bank), but by government-to-government agreements. The Rhodium Group estimates that such bilateral contracts represented over two-thirds of all Chinese overseas railway projects over the 10 years prior to 2019.[218] Effectively precluding foreign firms from participating, these contracts are typically negotiated by senior Chinese government representatives on behalf of consortiums of Chinese firms that are able to provide comprehensive packages of generous financing and all the relevant products and services. The Export–Import Bank of China (Exim) and China Development Bank often finance 70 to 90 percent of the deals at below or near commercial interest rates, and with attractive interest-free grace periods and long repayment periods. These contracts typically require Chinese firms to provide the vast majority of the contract value.[219]

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The Chinese government has committed huge amounts of capital to help Chinese firms win rail projects around the world. A 2017 *Financial Times* and Center for Strategic and International Studies (CSIS) report estimates that the total value of 18 Chinese overseas high-speed rail schemes was $143 billion. To put this into context, the U.S.-led Marshall Plan, which helped revive Europe after World War II, would cost $130 billion today.[220] In 2017, the China Exim Bank signed an agreement with CRRC to provide 200 billion yuan (about $30 billion) to enable it to market its technology abroad.[221] For example, in October 2015, Japan lost out to China on a $5 billion deal to export high-speed rail to Indonesia. In June 2019, China Exim Bank provided

CRRC with $2.4 billion to help Iran build a high-speed rail line between Tehran and Isfahan.[222] It is currently providing $10.5 billion (about 85 percent of total costs) for the on-again/off-again high-speed East Coast Rail Link project in Malaysia.[223]

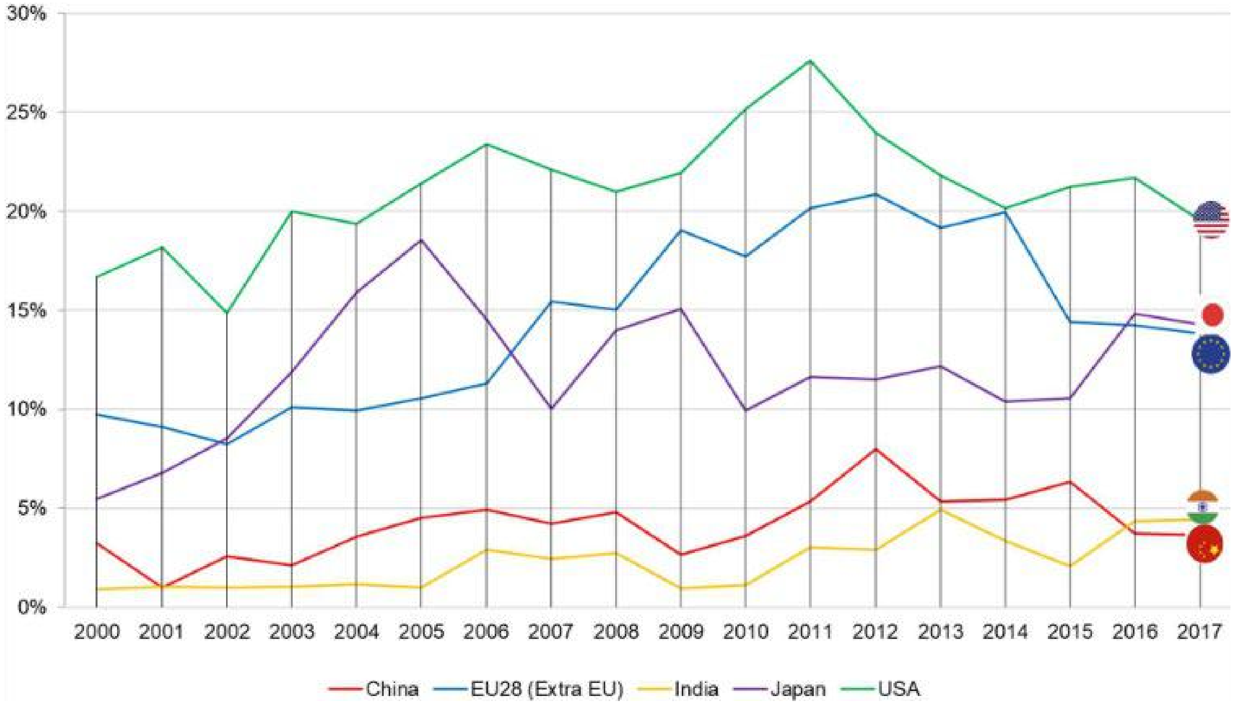
Concerns about China's "debt trap diplomacy"—wherein China forgives a country's debt in exchange for its strategic assets—often involve high-speed rail projects.[224] This is especially true when the sheer size of the financing overwhelms small developing countries interested in high-speed rail projects. For example, China's Exim Bank is providing 60 percent of the financing for a $5.8 billion high-speed rail project in Laos. With a total annual GDP of $12.5 billion in 2015, it's hard to see how Laos can justify and pay the cost of a high-speed rail project (which both the Asian Development Bank and World Bank considered unaffordable).[225]

## China's Success (and Failures) in Global Rail Markets

China is the largest player in a global rail market that faces slower growth and, overall, growing market restrictions.[226] Chinese rail firms such as CRRC need to expand overseas because, as is so typically the case with Chinese state-directed industrial policy, the home market is reaching maturity and over-capacity. As figure 1 shows, rail production in China far exceeds that of every other country. Rail industry experts estimate that China's supply of freight wagons exceeds domestic demand by 50,000 cars, the supply of metro cars exceeds domestic demand by 4,000 cars, and the supply of high-speed trainsets exceeds demand by 200 cars. This is despite the fact that the first generation of Chinese high-speed trains is not expected to be replaced until the 2030-to-2040 timeframe. Following large and heavily subsidized investments in new rolling stock after 2018, the main market for rail cars and engines is forecast to decline after 2020. Domestic growth between 2020–2022 is expected to be only 0.6 percent. Indicative of how reliant Chinese firms are on domestic sales, in the first half of 2015, CRRC earned 88 percent of its sales domestically, despite its domestic sales growing only 0.9 percent year on year. Meanwhile, CRRC's revenue from overseas sales jumped 61 percent year on year.[227] As China builds out its high-speed rail network over the decade, overseas expansion will become even more critical for Chinese rail companies' continued growth.[228]

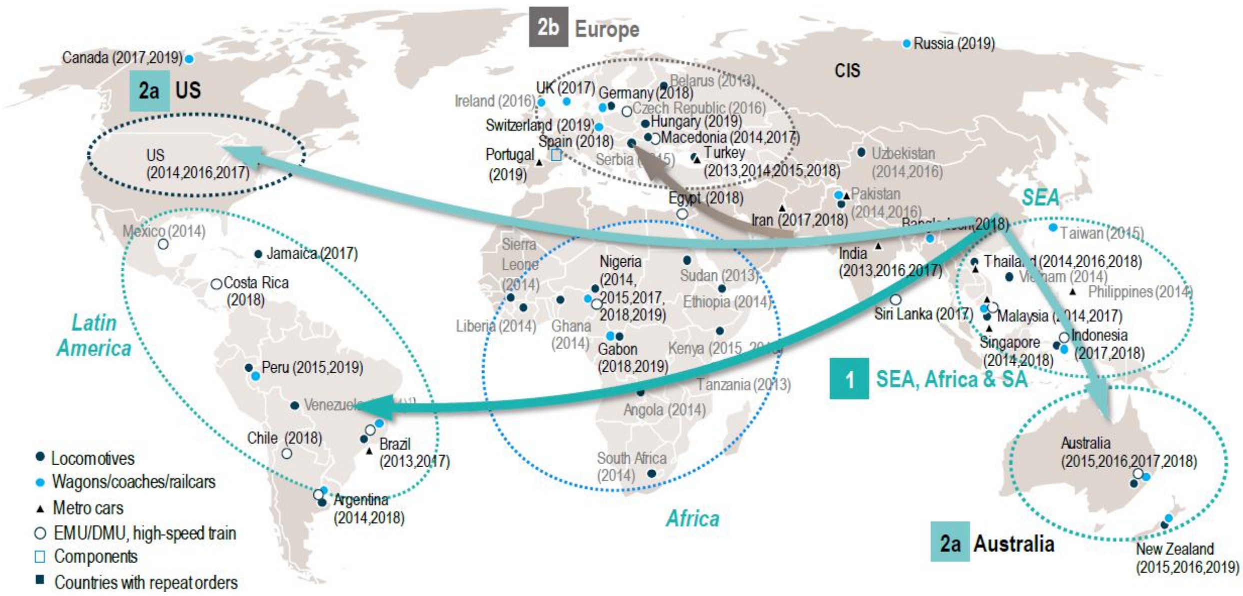
China's rail exports have grown over the last two decades, albeit in fits and starts. China's exports of locomotives and rolling stock have experienced periods of rapid growth, with average growth of 24.1 percent between 2000 and 2008 and 46 percent per year between 2009 and 2012. Exports from China peaked at €3.9 billion in 2015. Yet, general rail exports from China remain lower than those from the EU.[229] Similarly, China has much lower export intensity (exports measured as a percentage of production) than other major countries. As figure 8 shows, exports represented less than 5 percent of its total production in 2017, which compares with around 13 to 14 percent for Japan and the EU, and 20 percent for the United States. This highlights the fact that, although most Chinese rail firms remain dependent on it, given the maturing nature of the domestic Chinese market, increasing exports will be central to these firms' growth. Hence the government's efforts to help them go global.

**Figure 8: Rail export Intensity of locomotives and rolling stock (percentage defined as export/production)**[230]




CRRC's global expansion is indicative of China's growing ambitions (see figure 9, and annex 3 for projects in Europe). CRRC has become a major player in the $110 billion international rolling stock market. It has completed, or at least competed for, projects in several developed and developing countries.[231] CRRC has expanded its market presence in 104 countries and regions across 6 continents. From 2013 to 2017, CRRC's foreign assets increased tenfold to $4.9 billion. In a since-deleted tweet, CRRC stated, "So far 83 percent of all rail products in the world are operated by #CRRC or are CRRC ones. How long will it take for us conquering the remaining 17 percent?"[232] These orders had a major impact on broader rail operations. In 2014, CSR's overseas orders reached $3.76 billion, an increase of 68.6 percent over the previous year. For CNR, that figure was $2.99 billion, an increase of 73 percent compared with the same period the previous year.[233] S&P Capital IQ estimates that CRRC's international sales have hovered around 9 percent of total revenues since 2015.[234]

**Figure 9: CRRC's expansion path and major orders worldwide (2013–2019)[235]**




Foreign sales can be used as a proxy for judging the level of technological sophistication and international operational experience of Chinese rail firms. Many Chinese firms set—and usually fall far short of—lofty international sales goals. For example, CRSC, the world's largest provider of rail transportation control systems, signed only 10 percent of its 2018 overseas annual target in the first half of that year. However, many Chinese firms are clearly becoming more competitive and successful in global markets.

In 2018, China High-Speed Railway Technology Co. earned less than 2 percent of its revenue from international markets, CRSC had around 5 percent, CRRC and Nanjing Kangni Mechanical and Electrical Company had between 5 and 15 percent, and only a very few (e.g., Jinxi Axle Company) had more than 15 percent.[236] This reflects their relative level of technological sophistication, in that those with fewer international sales are largely integrating foreign technologies for the domestic market, while those at the next level take their first steps in exporting to third-tier foreign markets involving relatively simple products. Those at the next level, such as CRRC, are established as acceptable low-cost providers that largely export to second-tier markets involving small- and medium-sized contracts, with some limited (but growing) sales and projects in developed markets. Finally, having already mastered specific technologies, Jinxi Axle Company and a select few other firms continue to innovate and export high-value goods to global markets.

China’s Belt and Road Initiative (BRI) strategy creates much needed new markets—largely in developing countries—that Chinese rail companies such as CRRC need.[237] High-speed rail projects exemplify the type of infrastructure project BRI seeks to promote: large, infrastructure-based projects using Chinese products, financing, and expertise.[238] China’s 13th Five-Year Plan includes a dedicated section on BRI in which it mentions that it will encourage “more of China’s equipment, technology, standards, and services to go global by engaging in international cooperation on production capacity and equipment manufacturing … with a focus on industries such as … railways.”[239] CRRC is a government-designated rail supplier for BRI.[240] For example, the high-speed rail project in Laos is part of BRI.[241]

However, China's global high-speed rail ambitions have experienced multiple setbacks with the delay, reduction, or cancellation of projects in Indonesia, Libya, Mexico, Myanmar, the United States, Venezuela, and Thailand over regulatory, financing, and transparency concerns.[242] According to the 2017 *Financial Times* and CSIS study, the combined value of cancelled foreign high-speed rail projects was $47.5 billion.[243]

For example, CRCC led a consortium that won a $3.75 billion high-speed rail contract in Mexico in 2014 (it was the only bidder), only to have it canceled due to cuts to Mexico's national budget in 2015.[244] The Philippines is paying loans to China's Exim Bank for a railway that never got built. China demanded the repayment of the first part of the loan ($185 million) while the two countries were locked in a border dispute in the South China Sea.[245] In Thailand, the government pushed back negotiations on a high-speed railway (due to COVID-19) that would eventually span the length of the country to connect to the broader regional network with China. It will instead focus on a 250 km section of the link from Bangkok to Nakhon Ratchasima.[246] In Indonesia, the joint Sino-Indonesian JV to build the country's first high-speed rail line between Jakarta and Bandung (for an estimated $5.5 billion) has been beset by delays.[247] Indonesia recently announced that it plans to extend this high-speed rail line from Jakarta to Surabaya (about 760 km to the east) as part of national strategic projects for the 2020–2024 period and that it plans to bring in Japanese partners for the project.[248]

## A Harder Nut to Crack: Entering and Competing in Developed Country Markets

Entering and competing in developed markets is not as straightforward as simply exporting products or entering developing markets in which local contracts ensure Chinese firms build the infrastructure and provide most of the content and expertise. Annex 2 provides a detailed breakdown of CRRC and others' efforts to gain a foothold in Europe's rail market. For example, Europe's regional technical standards and networks—mostly built around Siemens or Alstom technology—represent a high barrier for new entrants. Manufacturers must prove that their products are safe and compatible and pledge to provide decades of maintenance.[249] This is challenging for Chinese and non-Chinese rail firms alike: Bombardier built its European railway presence through multiple acquisitions, and Japan's Hitachi took around a decade to win its first supply contract in the EU.[250]

While Chinese rail companies have had some success internationally, they are not yet significant players in key regions, especially Europe and North America. However, China has made some inroads in developed markets, winning rail contracts in Australia, Europe (as in figure 8 and detailed in annex 2), New Zealand, and the United States, all the while undercutting Alstom, Bombardier, Hitachi, Siemens, Kawasaki, and other firms by getting much of their technology for free and then enjoying massive government subsidies for production and exports. As detailed, Chinese rail firms have had some success in the United States, especially in metro rail projects. Indicative of this, Chinese exports of locomotives and rolling stock to the United States represented 42 percent of all imports in this segment in 2018.[251]

While the United States lags far behind China in terms of high-speed train lines, Chinese firms have been eager to play a role in the few American projects that already exist. As part of China's brief involvement in California's ongoing effort to build a high-speed train line between San Francisco and Los Angeles, China's MOR agreed to license technology to GE.[252] Without a trace of irony about how China came to be so competitive in high-speed rail, Zheng Jian, director of high-speed rail at China's MOR said, "We are the most advanced in many fields, and we are willing to share with the United States."[253] And China generously offered to not only build California's high-speed trains, but even finance some of the construction (no doubt out of its massive trade surplus with the United States). Of course, California would still have to invest billions, including for Chinese rail components and engineering services. Furthermore, in 2015, a consortium of Chinese rail firms teamed up with a U.S. company, Brightline West (formerly known as XpressWest), to build a high-speed rail line between Los Angeles and Las Vegas.[254] However, soon after, Brightline West cancelled the agreement, citing U.S. local content requirements.

CRRC and other Chinese high-speed rail companies face growing challenges to taking part in high-speed and metro rail projects in the United States (as detailed earlier, with CRRC winning contracts in Boston, Chicago, Philadelphia, and Los Angeles). Former President Trump signed legislation that bans Chinese rail and bus manufacturers from receiving federal transit dollars, as many U.S. policymakers consider CRRC a national security risk whose market presence is the result of unfair subsidies.[255] The Biden administration's proposed expansion of Buy America policies would also make it more difficult for China's entrants to compete in this sector in the United States going forward.

**While Chinese rail companies have had some success internationally, they are not yet significant players in key regions, especially Europe and North America. But China has made some inroads.**

U.S. policymakers also need to consider the broader, indirect effects of unfair and subsidized competition from CRRC and other Chinese rail firms.[256] While the last American firm to make passenger rail cars, the Pullman Company, produced its final car in 1981, Greenbrier Companies, TrinityRail, and other American firms that manufacture freight rail cars and other rail components fear that any foothold CRRC and other Chinese rail firms gain in the United States will eventually lead to them entering their markets.[257] CRRC's entry into Australia (albeit a much different market) provides a cautionary tale. In 2008, Bredken, Australia's largest rail car manufacturer, had 40 percent of the market. But by 2017, only a year after CRRC had entered the rail car industry, Bredken had exited the freight and passenger markets, as CRRC had claimed both.[258]

China's push for high-speed rail dominance is a particular challenge for Europe, given it is a major market and home to leading high-speed rail firms. China's exports of locomotives and rolling stock products to the EU increased from €137 million to €213 million from 2014 to 2017.[259] The European rail supply industry directly employs over 400,000 people and millions more indirectly in related sectors.[260] Despite Alstom and Siemens's leading positions, the EU's is far from assured in the future. In 2017, the EU recorded a positive trade balance for rail products of around €2.2 billion.[261] However, the value of EU exports has been on the decline since 2012, largely due to the deteriorating accessibility of export markets such as China's. While EU exports have stagnated, the global rail market grew by 1.2 percent per year from 2013 to 2017, reaching a value of €163.2 billion.[262]

## TESTING THE HYPOTHESIS: ASSESSING THE COMPARATIVE INNOVATION PERFORMANCE

This section analyzes a central question: in the18 years since China shifted to a mercantilist development strategy, what has the impact been on innovation in the global high-speed rail sector? This section uses publicly available statistics on country- and firm-level analysis of R&D spending and R&D staff and global-, regional-, and country-level IP data to provide a comparative assessment of high-speed rail sector innovation.[263] Overall, top non-Chinese high-speed rail firms lead their Chinese competitors in terms of innovation and technology, but China continues to spend huge amounts of financial resources and effort on their own R&D and acquiring foreign technology, know-how, and project experience, so they will likely close the gap.

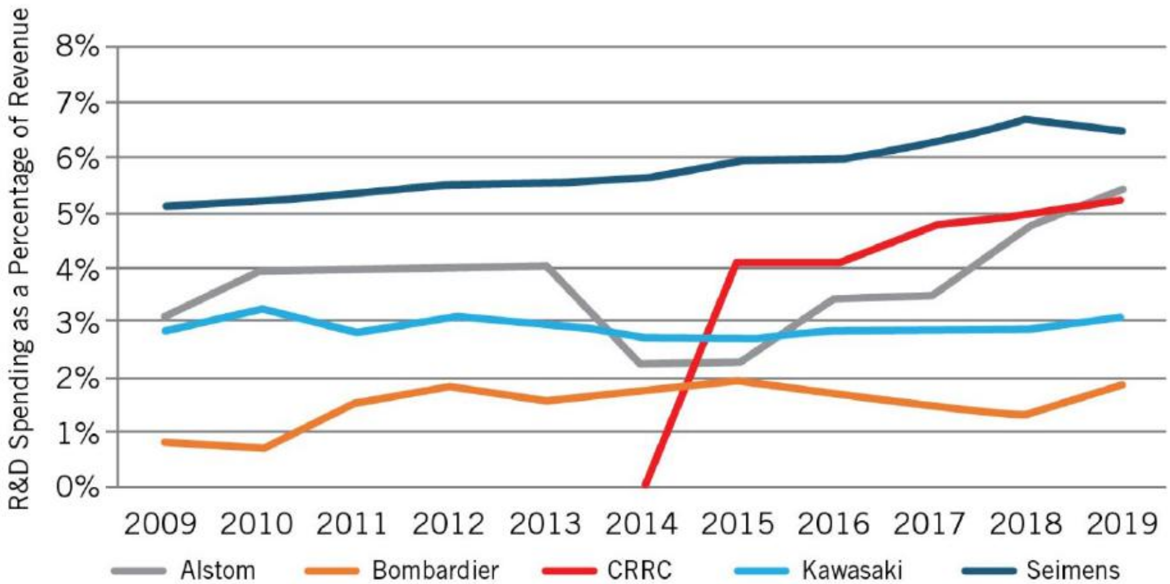
A comparative assessment of country and firm performance in high-speed rail is challenging. Comprehensive, comparable, and specific data on the high-speed rail segment and firms is lacking. Most statistics only deal with the broader railway sector (without breaking it down to the high-speed segment, such as World Intellectual Property Organization (WIPO) patent data).[264] Also, country-level data for rail sector R&D spending (such as in Organization for Economic Cooperation and Development (OECD) data) includes many relevant developed countries, but not China.[265] Also, differences in patent law and practices limit comparative analysis, especially given the non-innovation financial incentives to file for patents in China.[266] As academic research shows, such as Hu, Zhang, and Zhao's "China as number one? Evidence from China's most recent patenting surge" in the *Journal of Development Economics*, this type of non-innovation-related motive for acquiring patents has played an important role in the broader patenting surge in China.[267] CRRC and other rail firms use domestic patent filings to show China's political leaders that their technology is becoming more sophisticated and their huge investments are paying off.[268] Indicative of this, there were 124,538 railway patents granted in China between 2011 and 2017, compared with 17,873 in the United States, 8,587 in Korea, 8,8088 in Japan, and 3,636 in Europe.[269] This analysis therefore either disregards patent data from China's State Intellectual Property Office (SIPO) or notes (with caveats) where it is used.

Firm-level data also presents several challenges. Some firms do not specify rail division R&D spending and activities, such as Siemens (which is in many industries) and Bombardier (which also produced jets, until recently, when Alstom acquired its rail unit). Annual reports provide consistent firm-level data on R&D spending but are generally not broken down by division or segment, and therefore include non-high-speed-rail-related R&D activity. Moreover, Chinese firms have strong incentives to overstate their R&D expenditures when reporting to the government, in large part because the central government, in particular, looks at R&D spend as a key indicator of performance.

The European and Japanese rail industries' leading positions in high-speed rail are due to decades of investment in R&D, which is important, as the rail locomotive and rolling stock sector is a design-, engineering-, and patent-intensive industry.[270] Siemens leads in R&D investment as a percentage of total (all business unit) revenue, generally showing a gradual increase in R&D over the last decade from nearly 5.1 percent in 2009 to 6.5 percent in 2019 (see figure 10). However, given Siemens does not breakdown R&D spending by division, it is hard to know how much of this was dedicated to rail. Siemens's Mobility (which includes its rail operations) represented between 7.7 and 15.3 percent of total revenue between 2013 and 2019, so rail-specific R&D may only account for a small proportion of its R&D activities.

After its formation in 2015, CRRC's R&D investments increased from 4.1 percent in 2015 to 5.3 percent in 2019.[271] Alstom's R&D spending also increased in recent years from 2.4 percent in 2016 to 3.6 percent in 2019—which is barely above what it was spending between 2009 and 2012. Kawasaki and Bombardier have both invested relatively similar amounts on R&D over the last 10 years.

**Figure 10: R&D spending as a percentage of total revenue for major rail companies[272]**




Aggregating and comparing firm-level revenue and R&D spending and R&D revenue/spending ratios for the world's top 10 rail rolling stock reinforces how large CRRC is and provides a useful China versus the world comparative assessment (see figure 11).[273] Together, CRRC and CSRC are investing around two-thirds of what the other eight firms are spending on R&D combined. The average R&D/revenue ratio for these two firms is higher than that of their competitors: 4.7 percent compared with 3.3 percent.[274]

Comparing R&D staff with sales ratios provides a snapshot of the R&D intensity and efficiency of firms. Again, this analysis is indicative given issues with how firm's report relevant data. Due to both firms often counting staff (engineers and scientists as well as administrative staff) differently and the inefficient nature of large SOEs in China (including their bloated payrolls), R&D staffing does not necessarily translate into R&D prowess. But given Alstom and CRRC are the two largest mostly high-speed rail firms, they are the most appropriate to compare. In 2019, Alstom had 7,000 R&D employees, while CRRC had 2,555. Given respective annual revenue for that year of $9.19 billion and $33.1 billion, this results in a ratio of R&D staff to $1 billion of revenue of 762 for Alstom and 1,053 for CRRC.[275] This shows that Alstom, even though it is much smaller than CRRC, supports a much larger R&D program relative to its size. CRRC's revenues are over three times as large, yet its R&D staffing level is only 38 percent larger than Alstom's. It also points toward the potential for Alstom to support a much larger R&D program—

if it had the same market share as it otherwise would gain in a fairer and more open Chinese rail market.

**Figure 11: Total Chinese versus non-Chinese revenue and R&D spending (2019)[276]**

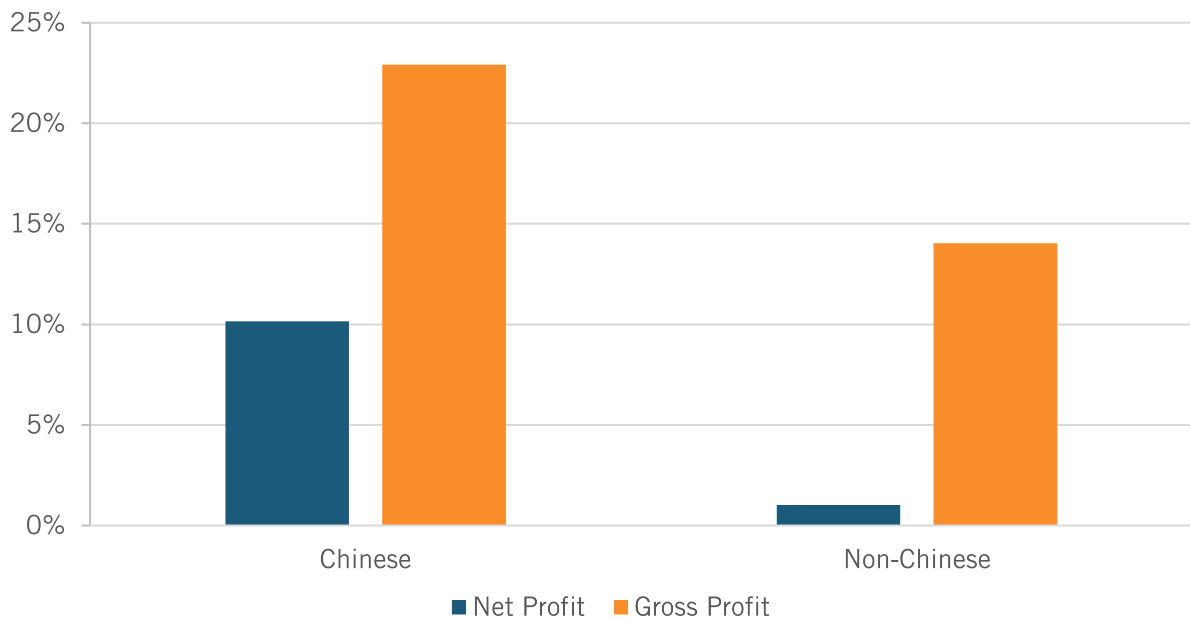

The battle for future high-speed rail innovation will not only depend on R&D staff and spending and patents, but, in part, on the size of each firm's respective installed base and ability to deliver complex, integrated projects. At the moment, non-Chinese firms retain a competitive advantage over CRRC due to their experience delivering integrated transport systems around the world, each meeting specific customer safety, environmental, and performance requirements. Alstom, Kawasaki, and Siemens have extensive experience as integrators in both their respective home markets and some foreign markets. However, CRRC also has its own extensive experience to build on at home as it completes a growing range of smaller projects while working toward its goal of securing larger and more complex train projects around the world. This becomes a bigger factor in the competition, as firms are able to develop innovations based on their installed bases. This obviously benefits Alstom and Siemens in Europe, although CRRC has a much larger installed base to learn from in developing and deploying current and future innovations—at huge scale.

**CRRC and other Chinese rail firms do not have to worry about profits in order to survive and invest in R&D—only the largess of the Chinese government and the closed Chinese market.**

## Comparative Analysis of the Profit Margins That Drive R&D Investments

As with all innovation-intensive sectors, the ability to reinvest in R&D depends on profitability (or in the case of CRRC, government support). A review of annual reports shows that, using an aggregated average, Chinese firms are far more profitable than their foreign competitors (see figure 12). Alstom's, Bombardier's, Kawasaki's, and Siemens's annual reports from 2015 to 2019 reveal that their aggregate average gross profit margin was 14 percent, and their aggregate average net profit margin was slightly more than 1 percent. A 2013 European Commission report into the EU rail sector's competitiveness highlights the sector's relatively low profitability—despite flagship domestic and overseas projects—and how this affects enterprises' R&D and their ability to maintain a technological lead.[277] This is significantly lower than CRRC's and CSRC's figures for 2015 to 2019, which show an aggregate average gross profit margin of nearly 23 percent and an aggregate average net profit of 10.1 percent.

**Figure 12: Chinese and non-Chinese average gross and net profit margins, 2015 to 2019[278]**




With the opaque nature of their operations and Chinese government support, it's hard to know the true extent of CRRC's and CSRC's profitability. But these figures could actually provide an indicative snapshot of how much support they received, given how large their profit margins were compared with their competitors, despite their home market being neither open nor competitive. There are also many factors that determine the overall performance of foreign rail firms. However, large profit margins point to the impact non-market-driven competitors have on the broader market, as CRRC and other Chinese rail firms do not have to worry about profits in order to survive and invest in R&D—only the largess of the Chinese government and the closed Chinese market.

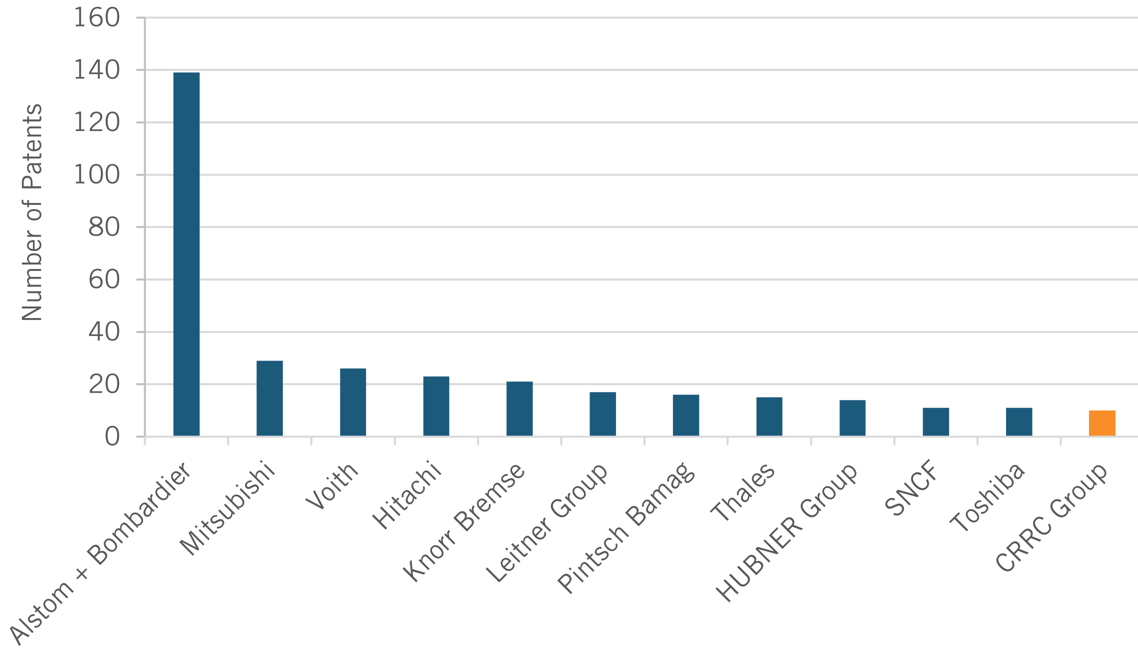
## Patents

Patents are an intermediate output for comparing knowledge production and innovation. However, as mentioned, the analysis only uses Chinese patent data selectively with appropriate caveats.[279] The analysis shows that China lags well behind in in terms of foreign jurisdiction-recognized IP.

European Patent Office's (EPO) Worldwide Patent Statistical Database (known as PATSTAT), which includes patent data from over 100 countries and regions provides an indicative look at how many patents leading rail firms hold around the world, albeit with two key caveats: it includes unreliable national patent data from China, and it involves patents from non-high-speed rail patents. The database shows that out of the 187,642 railway patents (a very broad category) granted worldwide between 2011 and 2017, it is estimated that 6,836 patents belonged to CRRC, 1,682 to Siemens, 823 to Central Japan Railways, 653 to GE, 621 to Kawasaki Heavy Industries, 423 to Alstom, 412 to Bombardier, and 410 to Hitachi.[280]

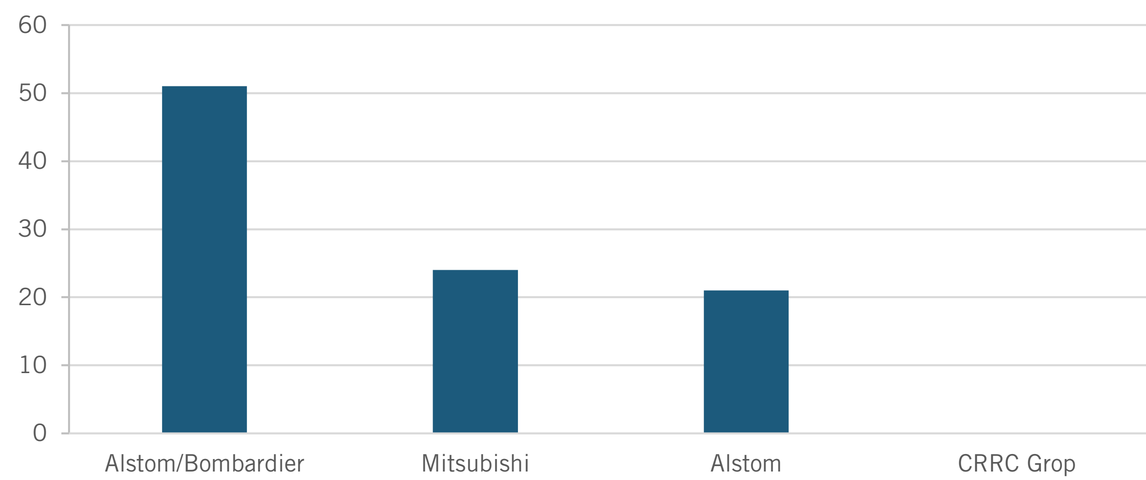
Analyzing data on patents only issued by EPO and the U.S. Patent and Trademark Office (USPTO) provides a more reliable assessment of comparative innovation in two large, developed markets. Out of the 3,636 railway-related patents granted by EPO between 2011 and 2017, 557 patents belonged to German companies, 149 to French companies, 103 to Japanese companies, and 67 to Canadian companies (see figure 13).[281] For rail-specific firms, Alstom and Bombardier had 139 patents combined, while CRRC only had 10.[282]

**Figure 13: EPO rail patents granted by company (2011–2017)[283]**



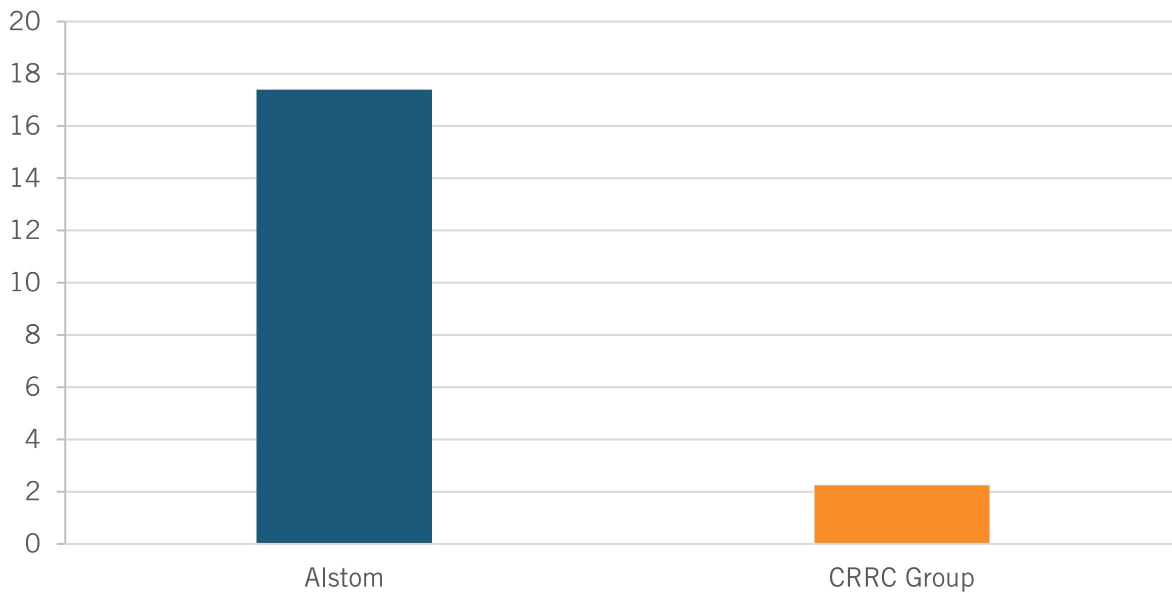

Similarly, USPTO data for key rail-related sectors for the same major firms in the EPO listing shows that Siemens, Alstom, and Bombardier are the leading patent holders, while CRRC does not hold any (see figure 14). However, given their growing operations in the EU and the United States, they may have filed patents more recently (the latest EPO and USPTO data is to 2017 and 2015, respectively).

**Figure 14: USPTO patents for key rail-related sectors by firm (2006–2015)[284]**



Using Europe and EPO data as a proxy, analysis shows that Alstom had a patent/revenue ratio of 17.4 from 2011 to 2017 (see figure 15). In comparison, CRRC had a ratio of 2.2. CRRC's figure is low, as CRRC is only a recent and relatively minor entrant, but the ratio is useful in how it shows Alstom's R&D program (which depends on both local and global market share) is relatively efficient in using R&D investments to produce new patents.

**Figure 15: Ratio of patents to revenue (EPO patents, billions of USD).**[285]




## Comparative Patents of Traction, Bogie, and Braking Technologies

A study into traction-, bogie-, and braking-related patents shows that China has the most, but that many of these patents are held by universities and research institutions that are unlikely to have commercialized the technology (in contrast, all major foreign patent holders in these technologies are private firms)—and few (if any) of these patents are in foreign jurisdictions. Again, the low quality of Chinese patents means comparative analysis needs to take into account the financial and non-innovation incentives for Chinese universities, research institutions, and firms to file for patents. Even so, the study provides useful insights into the relative strength of foreign firms in three key high-speed rail technologies, but that CRRC will inevitably try to translate some of its large number of patents and R&D investments in these technologies into actually useful technology.

This 2019 study by academics in China—"Identifying Technological Innovation Capability of High-Speed Rail Industry based on Patent Analysis"—focused on patents in key high-speed rail technologies: traction, bogie, and braking technologies. Traction technologies convert electrical energy (such as via pantographs) to mechanical energy in order to power trains. Bogie technology involves the complex underframe that houses train wheels and braking and drive systems. Braking technology involves aerodynamic, electromagnetic, and other types of braking systems. This study used Innography, a commercial database and search service for patents from more than 90 countries and regions around the world, as well as other data sources such as financial, litigation, market, and business databases.[286]

The study analyzed the number of patents among nations, the overall position of top firms, and the top firms in the three key technologies. Overall, China (1,539) was the most-active country in high-speed-rail patents, followed by the United States (205), Germany (130), and Japan (117). However, again, analysis should discount the value of China's domestic patent statistics. Together, the four countries accounted for 90 percent of global patents. In terms of the number of patentees, China had 14, Japan had 2, and Germany, France, Canada, and Sweden each had 1.

The study analyzed "high strength" patents in the three key high-speed rail technologies: traction, bogie, and braking. It used a 1–100 scale (with 1 being weak and 100 strong) developed by Innography that assesses various characteristics to determine the value of a patent, such as the number of patent claims, the types and number of patent citations, the number of different International Patent Classifications, the location of the patent assignee, and other indicators. Along its 1–100 scale, if a patent's strength is more than the 80th percentile, Innography deems it a "core patent." It is an "important patent" if it is in the 30th–80th percentile. While imperfect (for example, due to the differing underlying quality of patents granted in China), the consideration of various metrics along a scale provides an indicative insight into relative patent value.

As of November 2018, the study had identified 2,197 "important patents" related to high-speed rail.[287] The top three assignees all came from China, namely CSR/CRRC (80), Southwest Jiaotong University (54), and Beijing Jiaotong University (42). However, when the study (in a patent map) also considered the competitive position of the firms and measures of actual patent value (citations, patent location etc.), it is clear that foreign firms (in general) and their patent portfolio were much stronger and more valuable, with Hitachi (with 20 important patents), Siemens (23 patents), Alstom (15), and Bombardier (21) doing better than all other Chinese organizations except CRRC (22).[288] It's worth highlighting that many of the top patent holders in China were universities and research institutions, whereas every foreign patent holder was a private firm (which is indicative of patent weakness/strength).

The study found 148 "high strength" patents for traction technologies, 126 for bogie technologies, and 238 for braking technologies. Again, Chinese assignees le\d in all technologies, with Siemens being the highest-ranked foreign firm (with a total of 17 in the 3 categories). Alstom had 10 patents in the 3 technologies. However, in traction technology, most assignees were Chinese universities, which raises another point of caution, as this could be due to a major lack of industry-university collaboration and commercialization, a low-quality patent, a potentially infringing patent (in that the university had simply copied foreign technology in order to file and receive a patent), or some mix of the three issues.[289]

In conclusion, the study (implicitly) recognizes that the large number of Chinese patents is not what it seems to be in recommending that Chinese firms and the government speed up the pace of securing foreign patent protection in major markets as part of their "go global" strategies, as otherwise they risk litigation if their technology is based on existing (infringed) patents.[290]

### Comparative Patents for Vibration Technologies

Vibration-reduction technology is critical to high-speed rail development, as vibration decreases both train safety and the comfort of passengers. It involves rail vehicle suspension systems, train frame design, couplings, and springs, shock-absorbers, and other means of damping vibrations. A

2014 study of Chinese patents for vibration technologies involved in high-speed rail provides similar analysis in showing many low-quality domestic patents in China, with no evidence of consistent innovation. Based on data from the SIPO and WIPO Patent Cooperation Treaty (PCT) database, the study reviewed vibration technology patents for high-speed trains between 1985 to 2009.[291]

The study used vibration-specific keywords, and a review, to identify patents that were specifically related to high-speed rail (and not freight trains or slow-speed passenger trains). As of February 2011, the study had identified 193 relevant patents in China. The first patent application filed with SIPO was from Mitsubishi Electric Corporation in 1985 (replicating a patent they had already filed in Japan). From 1985 to 1997, there were one to three filings per year, but they were largely discontinuous applicants in that they were unique applicants or non-repeat applicants. These patents were one-offs that were either a byproduct of research in other fields or from an inventor/entity that invented one thing but went no further due to lack of effort, funding, success, or some other reason. If the data showed that the same entities applied for patents year after year, it would also show that the entities were making sustained progress and that their R&D efforts were showing signs of success. But this was not the case with vibration technology.

Starting in 1998, as MOR began increasing the speed of China's commercial train service, so too did high-speed rail R&D. There was a slight increase in patents filed from 2004 to 2009, which corresponds with China's 2004 launch of strategic industrial plans for high-speed rail development in China.[292] From 1998 to 2009, patent filings increased to seven to eight annually.[293] From 1985 to 2009, various CNR and CSR subsidiaries were among the top applicants, accounting for around 32 percent of all filed patents. During this same time, foreign firms represented nearly 12 percent of all applicants and 7.4 percent of all filed patents. The vast majority of patents were filed by domestic firms, individuals, and research institutions. It also found that the ratio of invention and utility model patents (a common way to measure the quality of a patent portfolio) across the years indicates poor patent quality (generally one-third invention to two-thirds utility model patents).

Also, although China's national development plans may have produced a short-term stimulus effect (in terms of the number of patents), the study did not observe a permanent effect in terms of firms filing a consistent or growing number of sophisticated patents over time, with more than 92 percent of applicants having filed patents in only one or two years between 1985 and 2009. Furthermore, the actual time patents (especially invention patents) were in force was short (only a few years), as patentees generally chose to stop paying the required annual fees. Of the 193 Chinese vibration-related patents, the study found only 1 application from China in WIPO's PCT database.[294] Taken together, these statistics again point to the development of poor-quality statistics. While this study was from an earlier era, it is indicative of China's ongoing approach to innovation in high-speed rail and many other strategic technology sectors.

### Comparative Patenting of Bogie Technology

The bogie—the complex underframe that houses train wheels and braking and drive systems—is a key component for high-speed trains.[295] Different bogies are designed for different speeds, loads, and power requirements. Bogies can be characterized by whether they have an engine (e.g., motor bogies and track bogies), the number of axles (e.g., two-axle, three-ale, and multi-axis bogies), and axle positioning (e.g., pull-type, rod-type, arm-type, laminated and dry friction bogies). The Alstom CL334, Siemens SF500, Bombardier Flexx Speed Italy, and Bombardier Flexx Eco5101 are the four most common bogies currently used in high-speed trains in Europe.[296]

A 2018 academic study used Google Patents to do an intergenerational patent citation analysis—which looked backward in time to identify which patents were cited through subsequent iterations of innovation—to analyze the development of bogie technology for high-speed rail.[297] In this way, it could use chains of patent citations to draw network trees of patents in different countries. The study found 1,099 patents using a key word search for bogie and related technologies (642 of them did not cite existing patents). The database includes patents from Japan, Korea, the United States, and other countries. However, it notes that some countries don't keep good records about patents, so the database may be incomplete. However, it is detailed enough to be indicative of the development and spread of bogie technology for high-speed rail.

Most primary patents cited for first-generation bogie technology (from the 1970s to 1990s) were by firms in the United States. Second-generation bogie technology patents (from the mid-1980s to 2005) were still mostly from the United States (29), but with a greater spread into Europe (United Kingdom 5, France and Netherlands 2, and Spain and Germany 1) and Asia (China 14 and Japan 1). For subsequent generations, the United States remained the home of most bogie patents (798), while other major centers of high-speed rail increased their overall numbers (China 22, Germany 16, France 10, Spain 6, United Kingdom 3, and Japan 2). The study shows that bogie technologies had been going through a period of sustained growth over decades, while patent citations show that the global spread of bogie technology was slow and on a small scale (and that the period of technological advancements was shortening, indicating that technology breakthroughs were accelerating.[298] For example, fifth-generation patents not only were focused on the bogie's physical components but expanded to modelling, integrated circuit layout, and communication technologies.

Overall, the study's analysis shows that China emerged as a growing patent holder for bogie technology, but that it (like every other country with high-speed rail firms, such as France and Germany), had obviously benefited from initial and ongoing bogie innovation that happened in the United States. However, again, it is hard to judge how valuable Chinese patents are. While the United States is not home to a leading high-speed rail firm, it is clear that it remains home to firms that are engaged in rail research and technology (although this may also reflect the fact that U.S. patent data is the most comprehensive). The study's specific focus on a key technology, and the fact that it was led by firms in a country that did not have its own leading high-speed rail firm, is also indicative of the importance of ensuring that the sector is based on comparative advantage and genuine cooperation between firms with different specializations (as opposed to China's efforts to control each and every piece of high-speed rail technology).

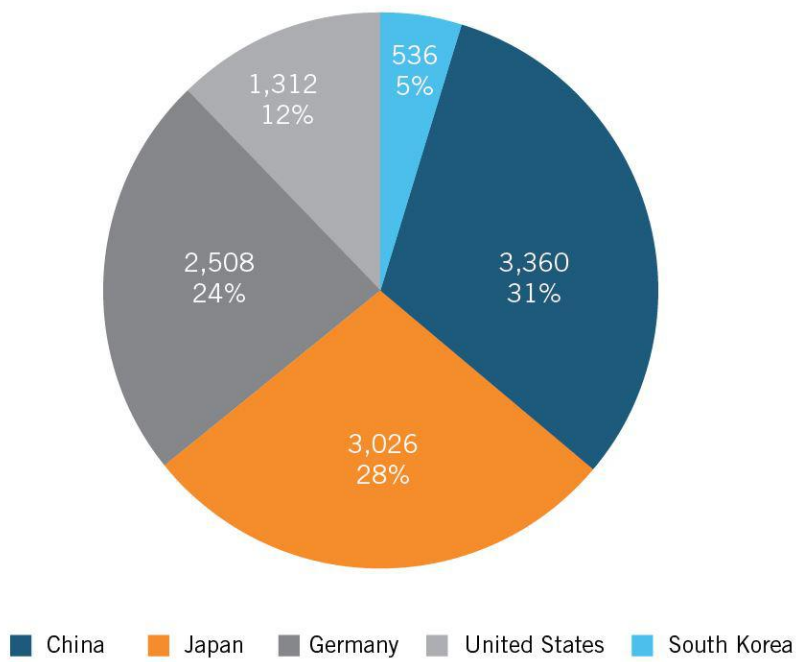
### Comparative Patenting of Maglev Technologies

The 2018 study "Development Status and Global Competition Trends Analysis of Maglev Transportation Technology Based on Patent Data" provides a comparative analysis of the development of maglev technology. Like prior studies, it used key words and specific WIPO International Patent Classifications to identify patents via the commercial IP search service

Innography.[299] The study also used unreliable Chinese patent data, and data from other countries (whose patent data was reliable), which thus provides a useful comparative assessment, especially given it shows how few patents Chinese firms held in foreign jurisdictions.

The search, conducted in November 2017, identified 12,269 patents. Patents for maglev technology had been growing—from 180 in 1998 to 721 in 2016.[300] Putting China's unreliable patent data aside, the top four countries for maglev patents were: Japan (3,026 or 24.7 percent), Germany (2,508 or 20.4 percent), the United States (1,312 or 10.7 percent), and South Korea (536 or 4.4 percent).[301] See figure 16. The overall number of patents (including China's) first peaked in 2004 with the introduction of the maglev line in Shanghai, before falling back into the 400s until 2013, after which it started increasing again as more firms in China filed for maglev-related patents.[302]

**Figure 16: Proportion of total maglev patents (from 1998 to 2016) held by firms of key countries**

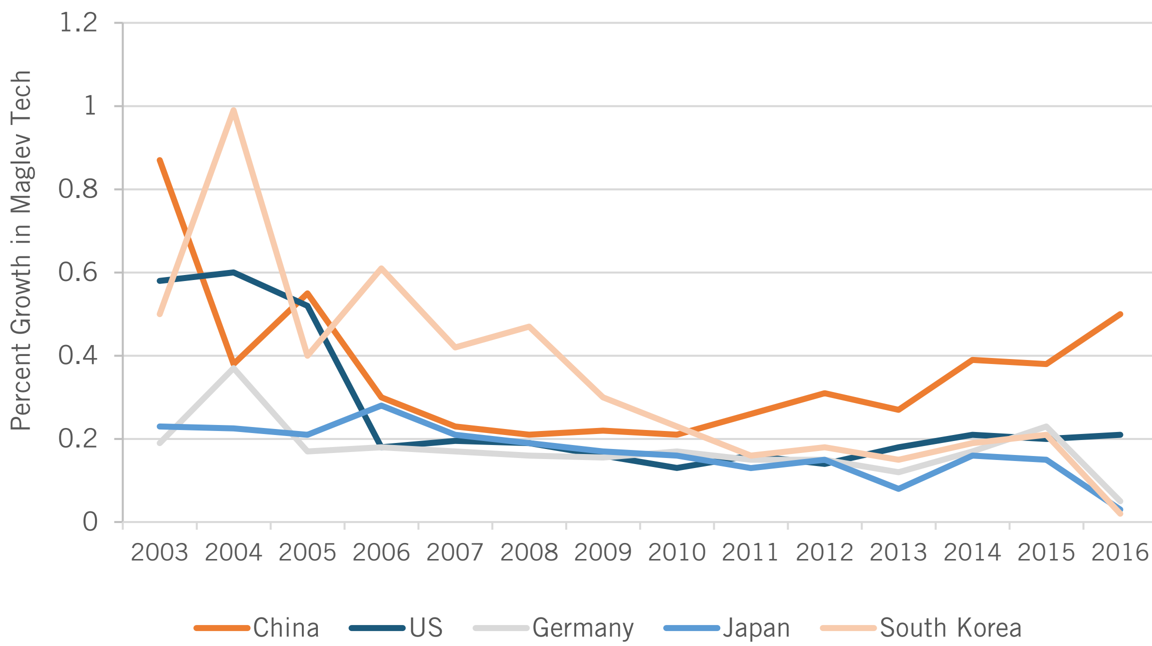



China granted the most maglev patents, but very few were registered in foreign jurisdictions. Of the 3,360 maglev patents in China, only 28 (less than 1 percent) were registered in another jurisdiction, compared with 56 percent, 55 percent, and 22 percent of patents from Germany, the United States, and Japan, respectively.[303] Today, firms from these countries tend to register their patents in 20–30 countries and regions, showing that their patents are valuable.

**China has granted the most maglev patents, but very few are registered in foreign jurisdictions.**

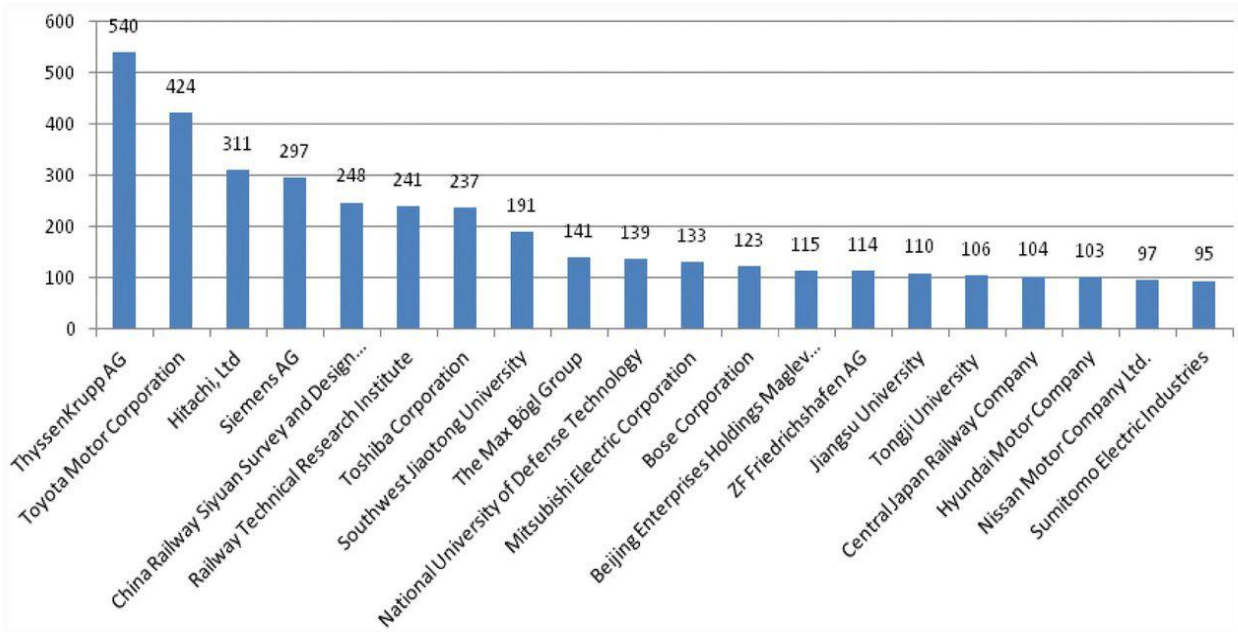
Shifts in patent activity are indicative of rising and falling levels of innovation in maglev technology around the world (see figure 17). But again, analysis needs to account for the generally poor quality of patents filed and granted in China. The 2018 study used a technology growth index to analyze the technology growth in patent-contributing countries by determining the patent growth rate (in terms of new patents and patent applicants compared with the previous five years). A rising rate shows the technology of a given country was in its infancy or growth stage (or in China's case, the result of non-innovation financial incentives for patents), while a declining rate shows it had entered a mature stage. As figure 17 shows, South Korea and Germany peaked in 2004, before maturing and decreasing, with a few minor rises. Meanwhile, Japan was relatively steady to lower over time. China started high, decreased until 2010, and then started to increase. According to this index, China became the world leader in 2011, and it only continued increasing since.[304]

**Figure 17: Technology growth in the top five patent-contributing countries on maglev technology[305]**




Firm level maglev patent statistics provide a more reliable comparative analysis, as they involve foreign firms' filing for patents in China (thus meaning they're likely to be genuinely valuable) and patents from multiple jurisdictions. The top five firms holding maglev technologies (ranked in order) were ThyssenKrupp AG, Toyota Motor Corporation, China Railway Siyuan Survey and Design Group (a CRRC subsidiary), Bose Corporation, and Hyundai Motor Company (see figure 18). ThyssenKrupp had 96 patents in China, 169 in Germany, and dozens of others in many other jurisdictions. Toyota had 30 patents in China, 36 in Germany, 292 in Japan, and anywhere up to 25 patents in a range of other jurisdictions. These firms had a relatively balanced geographic distribution of patents registered around the world, which shows that the patents were valuable and not solely focused on their domestic markets, and that these firms were actual leaders in the respective technologies.[306] In contrast, China Railway Siyuan Survey and Design Group had 239 patents in China and 9 at WIPO. It had no patents in Germany, the United States, Japan, United Kingdom, or other key markets. This lack of international patent protection is consistent with other high-speed rail technologies and points toward the lower value of China's domestic patents in this technology.

**Figure 18: Top 20 organizations with the most maglev-related patents.**[307]




An analysis of the classification of maglev patents shows that China was not a world leader (at least at this stage) in core maglev technologies. The data suggests that the top 20 maglev patent holders pursued a specialization strategy by generally focusing their resources on a single technology area in order to become a global leader.[308] The study shows that firms around the world were focusing their research on electric propulsion vehicles (22 percent), vehicle suspension control (18 percent), and railway systems and equipment (7 percent). For example, ThyssenKrupp AG focused on electric propulsion and machines for making railways (86 percent of its patents). For Hitachi, most patents were in propulsion, vehicle suspension, and railway systems (62 percent of patents). Firms from Japan and South Korea concentrated on energy savings and efficiency, with a particular focus on magnets, inductance, transformation, and the development of materials for magnetic properties as well as energy storage.[309]

Meanwhile, China's patent data shows that its firms were more focused on the railway construction, stabilization technologies, and vehicle suspension systems and bogies. The vast majority of China Railway Siyuan Survey and Design Group patents (81 percent) were in railway construction. While railway construction is a critical component in system design and deployment, it is not a core technology to the functioning of a train itself. It shows that China still relies on foreign technology for the actual train itself. Furthermore, perhaps highlighting the central role of the Chinese government and the lack of academic-industry commercialization experience, five of the six Chinese organizations in the top 20 of global maglev patent holders were universities and research institutes. By contrast, the vast majority of the other top patent holders were private firms.

When analyzing the strength of patents, it becomes clear that China's aggregate number was not as valuable as it first appears. It also highlights how the diversion of revenue for R&D would otherwise have gone to more innovative companies and specialized research. Indicative of this, the study also used Innography to identify "core" (and thus more valuable), "important," and "general" patents.[310] An analysis of all relevant maglev patents shows that 229 were identified as core patents, 2,557 were important patents, and 9,483 were general patents. Half of all core patents were actually held by U.S. firms, 22 percent by German firms, and 11 percent by Japanese firms. Only three core patents were from Chinese firms. This points to the innovation advantage foreign firms maintain over their Chinese competitors, but without greater IP protections, trade enforcement, foreign market openings, and domestic procurement market protection, the revenues (and IP) that support this lead will inevitably be unfairly taken by state-supported Chinese firms.

## Estimate: Impact of Chinese Mercantilism on Innovation in the Global High-Speed Rail Sector

CRRC took market share and revenue that otherwise would have gone to more innovative foreign firms. We used global market share and revenue estimates, data from firm annual reports, and rail patent data from USPTO to provide an indicative estimate as the impact Chinese high-speed rail mercantilism has on innovation.

Due to mercantilism, CRRC's global market share is around 70 percent, compared with Alstom's and Siemens's 10 percent each, Kawasaki's 7.5 percent, and Hitachi's 2.5 percent. Pre-mercantilism (around 2002), foreign firms had around 70 percent of China's high-speed rail market.[311] We used this pre-mercantilism market share in a "fair trade and market access scenario" for 2015 to 2019. It provides an upper bound estimate for foreign firms. In this, we assumed CRRC's market share to be 15 percent, compared with Alstom's 30 percent, Kawasaki's 25 percent, Siemens' 20 percent, and Hitachi's 10 percent. To provide a contrasting lower bound estimate (the "somewhat fairer" scenario), we assumed CRRC's market share to be 40 percent, contrasting with Alstom's and Kawasaki's 20 percent each, Siemens's 15 percent, and Hitachi's 5 percent. To assess the impact on innovation, we developed a revenue/patents ratio to assess the impact of redistributed market share and revenue. We used rail-related USPTO patents and global revenue (billions, USD) data from 2009 to 2015 (the latest data available).[312] Based on this data, the revenue/patent ratio for the non-Chinese firms examined in the study—Alstom, Bombardier, Kawasaki and Siemens—averaged $5.2 billion/patent.

In the fair trade and market access scenario, we estimated that the greater market share would have provided foreign rail firms with the revenue to invest an additional $1.06 billion in R&D from 2015 to 2019, which represents a 164 percent increase over their actual R&D spending (see figure 19). Given the revenue/patent ratio, these firms would have been able to develop an additional 13 patents (total) over this time, which is a 217 percent increase (see figure 19).

In the lower bound "somewhat fairer" scenario, we estimated that the non-Chinese high-speed rail firms would have earned the revenue to invest an additional $561 million in R&D from 2015 to 2019, which represents a 87 percent increase. This revenue would have resulted in an estimated additional 9 rail patents, which is a 150 percent increase (see figure 20). Given Alstom/Bombardier and Siemens were granted 49 and 23 patents, respectively, from the USPTO between 2006 and 2015, this additional R&D investment and patents represent a potentially sizable proportion of new technology under each scenario.

**Figure 19: Total R&D spending and patents by foreign firms as per the baseline, fair trade, and market access (upper bound), and the "somewhat fairer" fair trade and market access (lower bound) scenarios (2015–2019)**[313]

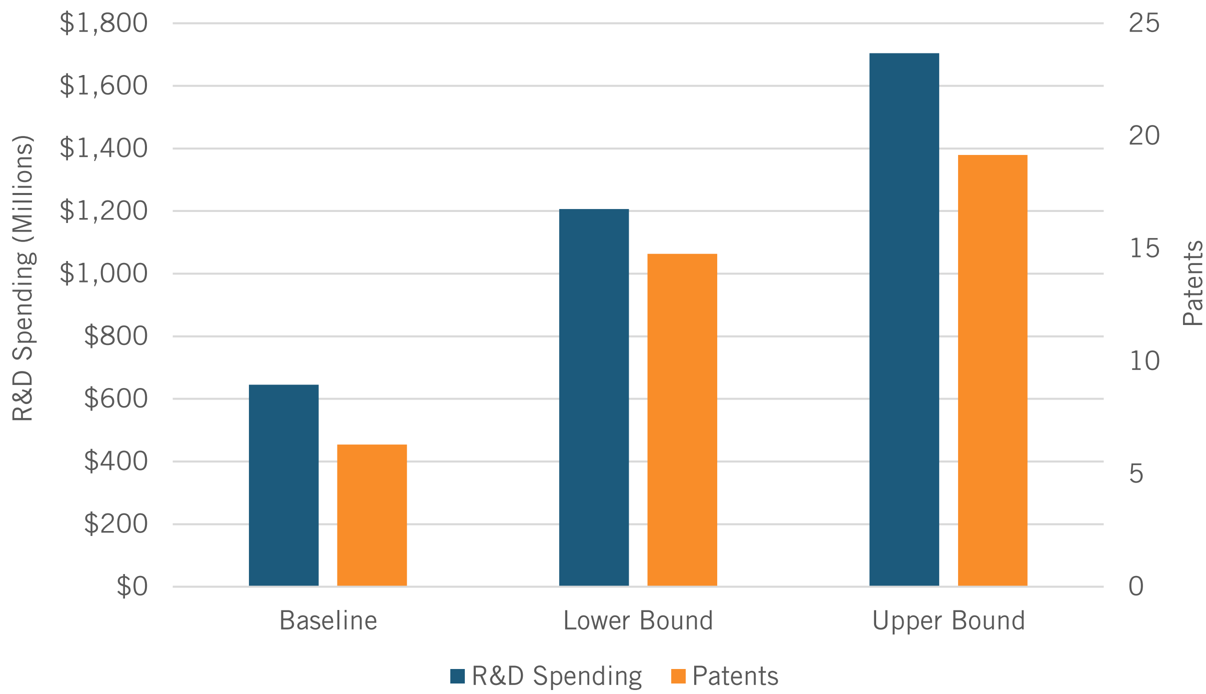
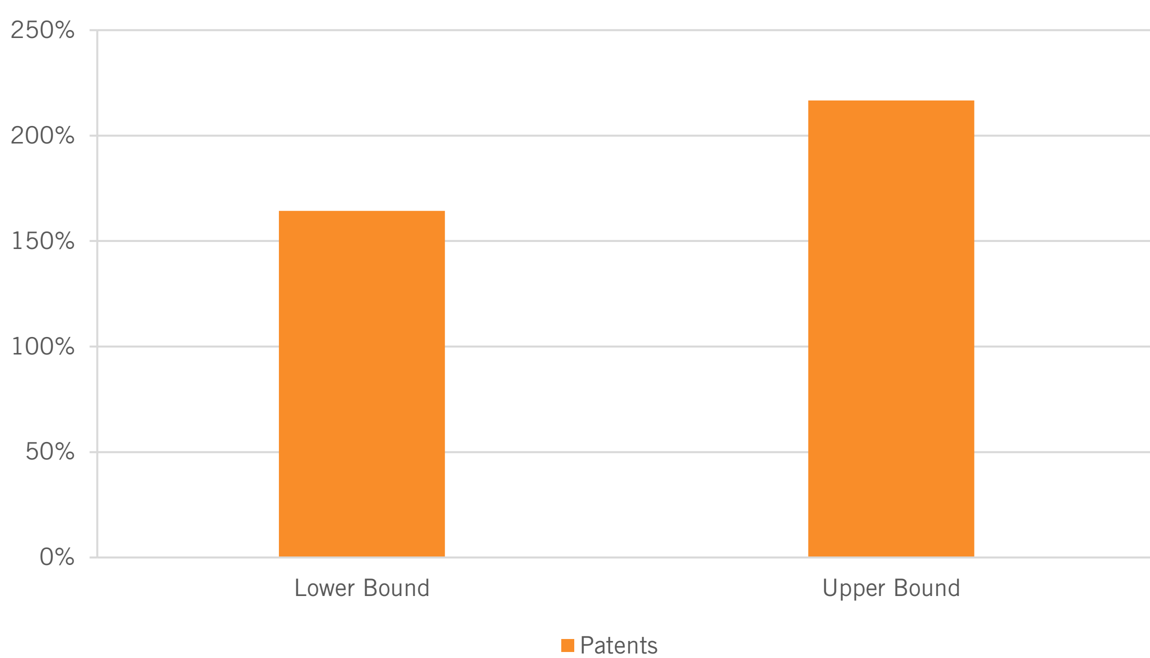



**Figure 20: Change in patents by foreign firms from the fair trade and market access (upper bound) to the "somewhat fairer" fair trade and market access (lower bound) scenarios (aggregated for 2015–2019)**



## POLICY RECOMMENDATIONS

Policymakers from Canada, the European Union, Japan, South Korea, the United States, and other countries interested in high-speed rail need to recognize China's (rail) track record. All of their rail firms—whether they're large or small, involved in metro, light, or regional or high-speed passenger rail, a component or core supplier—are at risk from China's ongoing approach of not just dominating, but controlling, all relevant technologies and markets that relate to rail, especially the high-speed rail segment. China's innovation mercantilist policies have allowed CRRC and other Chinese rail companies to gain global market share at the expense of companies that are more innovative, in turn slowing innovation in the industry. The challenge for policymakers is to address and limit China's market-distorting activities in domestic and global rail markets, including by building leverage via penalties for market-distorting firms and non-reciprocal market access, while doing a better job of supporting innovation by market-driven firms.

This section outlines recommendations for policymakers to consider if they want their rail producers to not only survive, but thrive, in the face of growing Chinese rail mercantilism. It is divided into two sections: restricting Chinese rail mercantilism and supporting market-driven firms and rail sector innovation.

**The challenge for policymakers is to limit China's market-distorting activities in domestic and global rail markets, including by building leverage via penalties for market-distorting firms and non-reciprocal market access, while doing a better job of supporting innovation by market-driven firms.**

### Restricting China

The odds of forcing—or even convincing—China to curtail its unfair industrial and trade policies in the rail sector are close to nil, as are the odds of foreign firms gaining any market share in China. What other nations can and should do is limit Chinese firms from gaining market share outside of China.

#### Block Chinese Acquisitions

Canada, the European Union, Japan, South Korea, the United States, and others should block Chinese acquisitions of local rail firms due to the fact they benefit from stolen IP and huge financial subsidies (see annex 3 for acquisitions). Acquiring firms that directly or indirectly receive state financing for acquisitions and major (general) foreign subsidies should be automatically rejected as they are neither fair nor market based. This should be the case even when a foreign acquirer makes a commitment to give up or forgo subsidies.[314]

Some countries already recognize the threat posed by Chinese state-backed and state-directed foreign investment from supposedly private Chinese firms that relate to specific high-tech sectors, and have revised their investment screening frameworks to give their respective governments the ability to stop these investments. The cumulative change to foreign investment screening laws in Japan, the United States, and the European Union (and elsewhere) over the last few years amount to a significant example of the collective concern about—and indictment of—China's predatory economic policies.[315] However, these countries need to add rail to the list of sectors they are watching.

Rail firms and technology do not attract the same attention semiconductors and other high-tech sectors do, so it's important that regulators recognize what specialist goods or services their firms provide. A first step is for countries to identify local firms that play both a direct and indirect role in the global rail market and rail innovation, covering relatively small and specialized component and service providers that support major rail manufacturers. Some of these firms may be small and otherwise fall under minimum thresholds that countries use as a trigger for mandatory foreign investment reviews.

This is particularly important in Europe, given its large rail sector. The EU was initially slow to realize its high-tech firms were being picked off by non-market-based, Chinese-government-supported investment acquisitions (the European Parliament first inquired about it in 2012, while Germany, France, and Italy presented a common position in February 2017).[316] While some EU member states have rejected attempted Chinese acquisitions in the semiconductors and advanced manufacturing sectors, they have yet to make it clear that the rail sector is also off limits. The German authority's approval of the CRRC acquisition of Vossloh Locomotives shows this.

**Europe's approach to reviewing Chinese foreign investment needs to improve if it wants its high-speed rail firms (and the rail industry as a whole) to have a fair chance of maintaining their leading positions in the coming decades.**

Countries should learn from and avoid repeating the German competition authority's April 2020 decision to approve CRRC's acquisition of Vossloh Locomotives, even after considering both the role of CRRC's state-provided subsidies and a survey that found that EU rail firms expected the merger to distort competition, noting that CRRC had access to "vast technological resources."[317] The German competition authority utterly failed to account for China and CRRC's strategic industrial plans and made its decision based on CRRC's current, limited market operations.[318] Vossloh may not have been the most competitive and profitable firm in the EU rail market, but it did have a significant share of its market—and it is simply unfair to allow a government-owned firm with essentially endless funds to acquire it. While it is impossible to know the counterfactual, a potential scenario would have been another firm competing on fair and level terms (eventually) acquiring it (even if at a lower price), thereby rewarding a firm that was successful due to its ability to compete and innovate on market-based terms—rather than the CRRC's (artificial) ability to compete based on state support and protection. Hopefully, it also would have helped the acquiring firm build economies of scale and scope, thus allowing it to become more competitive and innovative.

The EU should help individual member states improve their foreign investment screening frameworks (which is each member state's responsibility, hence there is no region-level investment screening framework). The EU's new framework for foreign direct investment (FDI) screening (which went into effect in November 2020) was a much-needed improvement in helping member states detect and respond to foreign investment in critical assets, technologies, and infrastructure in the EU. However, it did not harmonize investment screening frameworks, as it only set minimum requirements.[319] The effectiveness of Europe's evolving investment screening framework depends in large part on the European Commission, the EU, and member states working together to identify and respond to potential acquisitions in specific sectors.[320]

Europe's approach to reviewing Chinese foreign investment needs to improve if it wants its high-speed rail firms (and the rail industry as a whole) to have a fair chance of maintaining their leading positions in the coming decades—lest CRRC will chip away at their hard-earned gains, project by project and acquisition by acquisition, until it's too late and too hard to recover what was lost given the time, funding, and research involved in attaining leadership in advanced rail technology. While an individual acquisition of a minor player (or a Chinese firm winning a small project) may not seem like much at the moment, may seem to provide good value-for-money, and may help the EU's relationship with China in the short term, the long-term impact on the region's rail sector will likely be very different if the EU fails to recognize how each piece fits into China' strategic plans to dominate the sector.

### Create Fairer Procurement Markets

Public procurement plays a major role in high-speed rail projects, providing governments with a mechanism to promote innovation while screening out bidders for technology theft, unfair state-based financial support, and non-reciprocal market access. Canada, Europe, the United States, and others should use the considerable powers they have over domestic procurement contracts to exclude Chinese rail firms and work toward fairer international procurement markets.

Chinese rail firms are most successful when competing purely on price. Their international success is based in no small part on their ability to use vast amounts of low-cost financing to undercut competitors.[321] CRRC's competitive advantage is due to its ability to access financial and other subsidies to manufacture and deliver large volumes of products at (artificially) low costs. However, if rail market competition were to exclude unfair and market-distorting competition and instead be based on innovation, after-sales value-added services, and the ability to execute complex projects, the balance would shift back toward market and innovation-driven firms.

**Canada, Europe, the United States, and others should use the considerable powers they have over domestic procurement contracts to exclude Chinese rail firms.**

In particular, there is a lot the EU and its member states need to do. The EU still allows Chinese state-owned firms to bid and win rail projects in Europe that are financed by EU structural funds (also see annex 2). In 2020, the *Wall Street Journal* reported that Chinese companies won €2 billion in public tenders, more than double their wins in any previous year. From 2010 to 2020, Chinese firms won more than €4.5 billion in public tenders.[322] For example, the massive public procurement contract—nearly €1 billion for 40 to 80 electric regional trains—CRRC won in Romania was 85 percent co-funded by the EU. Similarly, CRRC is a player in Bulgaria's railways modernization, which also received EU funding. Technically, the Romanian government is free to choose its suppliers, so again, price-based assessments will favor subsidized state-owned companies such as CRRC. Before these cases, the European Commission both failed to fully recognize CRRC's strategy, and showed an inability to ensure EU funded projects use a stricter assessment criteria.

Price-only assessments for public procurement bids favor subsidized state-owned companies such as CRRC. In essence, other countries face a prisoner's dilemma. They all want the best deal, and many are unwilling to sacrifice for the global good, particularly to send a message to

China that may not have an effect for another decade or so. Still, countries take actions in other areas that violate the prisoner's dilemma challenge. Climate change is the best case in point. The rational thing for any individual country to do is to not implement climate measures that, at least until the world develops better technology, cost more than staying with dirty energy. But countries do pay the price and are willing to cooperate because there is a global consensus that not working to reduce greenhouse gasses is irresponsible. We need to a build a similar consensus among other nations in not rewarding innovation-harming mercantilist practices and policies.

Countries could do this via public procurement criteria that preclude bids from Chinese firms that have benefited from forced tech transfer, IP theft, massive subsidies, or being state-owned and not competing on price. For example, at the national level, the United States initially banned state-owned firms from receiving federal government funding to build rail cars and buses. This was in response to concerns about state ownership over Chinese rail firms, the unfair financial support they receive from the Chinese government, and unspecified fears that they pose a cybersecurity threat. However, this broad ban was later watered down. (It should be reinstated.) The 2020 National Defense Authorization Act included both a grandfather clause that permits CRRC to sell additional cars to current customers (Boston, Philadelphia, and Los Angeles metro systems) and a two-year grace period allowing CRRC to bid on any transit contract (except in Washington, D.C.).[323]

**Other countries should replicate the European Commission's Public Procurement Directive mechanism to allow contracting authorities to reject, under specific conditions, any tender they have determined to be "abnormally low."**

But if nations are not willing to go so far as an outright ban to punish past and current bad behavior, they could still replace lowest-bidder criteria with a best-quality-ratio assessment, allow contracting authorities to reject "abnormally low" bids based on an assessment of foreign state aid and subsidies, set national procurement standards that exclude firms that benefit from distortionary foreign state aid and subsidies, and provide guidance to national member states (in the case of the EU) and sub-national authorities (for the United States and elsewhere) to exclude abnormally low bids and firms that benefit from distortionary foreign state aid and subsidies. Similar proposals were part of a 2019, European Commission-arranged expert group report on the European rail supply industry.[324]

Countries could also support market- and innovation-based firms and preclude state-supported ones by setting ambitious design objectives in technical specifications—on quality, environment, innovation, and social criteria—for procurement tenders to encourage firms participating in the tender process to develop and propose new technologies and solutions. Countries could do so on the basis of the best quality price ratio (BQPR), also known as the most economically advantageous tender (MEAT) principle, which is a selection procedure wherein the contracting party awards the contract based on aspects of the tender submission other than just price.

For example, the Frecciarossa 1000 high-speed train project in Italy was based on MEAT principles with a technical offer weighing more than the price (30 percent) in specifying certain performance and environmental characteristics, such as carbon emissions, energy efficiency, noise, and recyclability.[325] However, as of 2019, around half of Europe's rail tenders were still based on the lowest price, although this has been decreasing.[326]

Thankfully, BQPR and MEAT-related criteria were at the heart of the EU's 2016 reforms of its public procurement framework.[327] This was a member state decision, not one made by the European Commission, so it and the broader EU rail sector will need to encourage more members to use this approach.[328] For public procurement, this is important preventative correction to the illusion of low price, which only holds in the short term. In the long run, maintenance costs or project execution might turn out to be more expensive than originally proclaimed, especially given the large sizes and long lifecycles of rail products.

Other countries should replicate the European Commission's Public Procurement Directive mechanism to allow contracting authorities to reject, under specific conditions, any tender they have determined to be "abnormally low". In 2019, the European Commission provided guidance to contracting authorities about how they could and should do this when an offer is well below other offers without a clear justification.[329] Where a contracting authority receives an offer it thinks might be abnormally low, it is under a legal obligation to request an explanation of the price offered from the economic operator concerned.[330] It can then reject abnormally low tenders if they appear to be due to state aid. However, as the expert's report points out, the rejection of abnormally low tenders is only mandatory when it is due to non-compliance with mandatory EU, national, or international laws on social, labor, or environmental issues.[331] The European Commission should add market-distorting state aid and subsidies to the list of issues for mandatory rejection.

Europe is also considering a separate, but complementary, legal framework—outlined in the white paper on levelling the playing field as regards foreign subsidies—to exclude firms that benefit from foreign state aid and subsidies.[332] The paper aims to promote the principle that not only price, but also high European standards, should be taken into account in public procurement procedures. Of note, it was the first deliverable of the 10 actions set out in the Communication on EU-China relations.[333] The white paper outlines a new tool whereby bidders would need to notify contracting authorities in advance that they, or any of their consortium members, have received financial support from a government within the last three years and whether such support is expected to be received during the course of the contract.[334]

This new framework would give the European Commission a greater and clearer role. A member state's procurement agency would conduct an initial review of notifications, and in cases wherein significant foreign subsidies were potentially identified, pass these notifications along to the European Commission and other government agencies, thus initiating an in-depth investigation. The European Commission currently asks for shared competency with national authorities to respond to notifications within a 15-working-day limit (in order to avoid delaying projects for extended periods). During this time, the procurement project would be suspended. If the review showed a market-distorting foreign subsidy, parties would be able to enact redress measures, such as banning offending firms from participating in public procurement tenders in the EU for three years.[335]

For international procurement, countries should revise trade and procurement policies to support the principle of reciprocity. China clearly doesn't provide the same reciprocal market access its firms enjoy in the United States, the EU, and elsewhere. Thankfully, more European policymakers recognize the lack of reciprocity and fair treatment. On June 9, 2016, the European Parliament adopted the Resolution on the Competitiveness of the European Rail Supply Industry, stating that, "While the EU is largely open to competitors from third countries, third countries have several barriers in place that discriminate against the European rail supply industry," and furthermore, "third-country competitors, especially from China, are expanding rapidly and aggressively into Europe and other world regions, often with strong political and financial support from their country of origin."[336]

The European Commission is pursuing new policies other countries could replicate in terms of building in the principle of reciprocity into rail procurement. In 2016, the European Commission launched an improved (but still draft) International Procurement Instrument (IPI) to promote a level playing field for international public procurement, especially with third-party countries such as China that are not GPA members.[337] (However, the future of the IPI is uncertain, as some key EU member countries—most notably, Germany—remain divided on whether and how to respond to state-subsidized firms). Building on the IPI, European Commission guidance established that "economic operators from third countries, which do not have any agreement providing for the opening of the EU procurement market or whose goods, services and works are not covered by such an agreement, do not have secured access to procurement procedures in the EU and may be excluded."[338] It thus created leverage for the EU to enact more-stringent requirements at home, while pushing for open procurement markets and fair treatment of EU firms abroad.

**Just as the United States, EU member states, and others are thinking about screening market-distorting firms from public procurement markets at home, they should ensure the World Bank does as well.**

### Stop World Bank Support for Chinese Rail Projects

Canada, EU member states, Japan, South Korea, the United States, and others should push the World Bank to stop all rail-related funding in China (it obviously does not need the funding) and engagement with Chinese firms that are obvious beneficiaries of its mercantilist practices.

The World Bank has directly supported China's mercantilist approach to high-speed rail at home. Between 2006 and 2019, it financed some 2,600 km of high-speed rail in China.[339] It funded and supported China's state-directed effort to build out high-speed rail, citing its approach as showing many best practices, while staying completely silent on its mercantilist practices. The World Bank has only alluded to the foreign nature of this technology and how foreign firms were forced to provide it, highlighting that much of the early technology for China's trainsets was foreign-derived.[340] The World Bank largely portrayed the situation as if China innocently and fairly adapted foreign technology for local use.[341]

Just as the United States, EU member states, and other countries are thinking about screening market-distorting firms from public procurement markets at home, they should ensure the World Bank does likewise, which is crucial, given its funding of rail and non-rail related projects in developing countries that may involve CRRC and other Chinese rail-related firms. Chinese firms captured as much as 21 percent of all World Bank transportation infrastructure project value in 2018, up from 12 percent in 2014.[342] Indicative of their broader role in transport infrastructure in developing countries, in 2019, the World Bank excluded CRCC and its 730 affiliates from bidding on World Bank contracts for nine months due to misconduct in relation to a road project in the nation of Georgia.[343] Unless the United States and other countries take action to permanently exclude CRCC, CRRC, and others, the World Bank will be further complicit in supporting Chinese innovation mercantilism in the rail sector by creating markets for them to export their excess capacity and state-subsidized production.

## Supporting Domestic Innovation and Market-Driven Firms

Canada, EU member states, Japan, South Korea, the United States, and others not only need to restrict China, but they also need to do more to help their own rail firms become more innovative and competitive.

### Expand Export Financing

Countries hoping to compete with CRRC need to provide more low-cost, and easy-to-access, export financing to help local rail firms compete with CRRC and other Chinese rail firms for foreign projects and sales. The slim-to-zero prospects for international cooperation (including at OECD and WTO) to discipline the use of export credit subsidies means countries have no choice but to do more, given China won't step back.[344] Large amounts of long-term, low-cost financing is one of China's main tools for seizing market share around the world. Yet, China's only real (financing) competition is Japan. Canada, France, Germany, the United States, South Korea, and others need to make it as easy as possible for their rail firms to access more financing if they want them to be able to compete.

China's export financing far surpasses all other countries'. In 2019, China's export-and-trade-related financing was estimated to be over $76 billion, of which official export credit was worth $34 billion. The contrast with the United States could not be starker. China's financing dwarfed the $5.3 billion provided by the Export–Import Bank of the United States (EXIM) in 2019. Never mind that EXIM was not even able to provide any financing over $10 million between 2015 to 2019, as it lacked a board quorum. Meanwhile, over this same period, China's export credit activity was equal to 90 percent of that provided by all G7 countries combined.[345]

European and Asian countries (especially Japan) do somewhat better than the United States, but still offer much less than does China. In 2019, France provided $6.2 billion in official export financing, Italy provided $11.1 billion, Germany provided $10.5 billion, Korea provided $5.8 billion, and Japan provided $36 billion.[346] These figures do not include trade-related financing programs and untied aid that relate to export promotion but fall outside official export credit statistics. Regardless, the story remains the same in terms of the United States and Europe being far behind China.

For example, in 2019, Asia accounted for roughly 80 percent of official investment financing support (China provided $23 billion, Japan provided $19 billion, and Korea provided $7.5 billion). Meanwhile, Germany provided $3.7 billion.[347] This is indicative of Japan being the only country that directly competes with China in terms of financing and direct support for its rail sector. Since 2000, the Japan Bank for International Cooperation (JBIC) has provided export loans, overseas investment loans, and untied loans to rail projects in Brazil, Egypt, the United Kingdom, Malaysia, and Turkey.[348]

Beyond providing more financing, countries (besides Japan) that are home to advanced rail firms need to explicitly support the sector. Advanced rail equipment is 1 of the 10 sectors China's export financing agencies are directly targeting in their role in supporting Made in China

2025.[349] EXIM provides funding for general railroad exports (including from Wabtec and GE), but it does not explicitly support advanced rail firms as part of recent efforts to better compete against China.[350] Congress's 2019 reauthorization of EXIM included the "Program on China and Transformational Exports" to provide financing at similar rates as China's and reserve 20 percent of the agency's total financing for this program ($27 billion out of a total of $135 billion).[351] While a welcome step in competing with China, rail is not 1 of its 10 priority industries. Likewise, EXIM's (2020) "Strengthening American Competitiveness" initiative targets a variety of advanced sectors, but nothing to do with rail.[352]

The United States (and others) also need to make it as easy as possible for rail firms to access and use export financing. For example, surveys of U.S. firms that want to use EXIM show that it's too slow and cumbersome, EXIM's foreign content policy requirements (50 percent) are far too high, and U.S.-flag shipping requirements are restrictive.[353] In contrast, since the mid-2000s, export credit agencies (including many in Europe) have dropped or generally made their local content policies more flexible, thanks to the fierce competition with China for export opportunities.[354] For example, Australia and Japan have broadened their export credit agencies' mandates away from a focus on local content and jobs to broader strategic and economic interests.[355] The United States should do the same.

### Host International Standards Discussions and Help Local Representatives Attend

The technical standards governments and national railway authorities require for high-speed rail projects play a critical role in determining who wins tenders. Not all firms have the same experience or technical know-how to meet these specific performance requirements, whether for safety or environmental outcomes, or to ensure each product works as part of an interoperable train system and network.[356] The global battle for market share and tech supremacy in the high-speed rail sector depends, in part, on the membership, leadership, and governance of the standards development organizations (SDOs) that determine which standards become central to high-speed rail technologies. In other sectors it identifies as strategic, China has shown it wants to unduly influence global standard setting processes by coordinating a unified position for Chinese firms and influencing foreign government officials and firm representatives to support their preferred outcomes. Canada, Europe, Japan, and the United States need to provide financial incentives to ensure their respective experts from local firms are able to attend and host SDO meetings.

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) are two key SDOs in which China and its firms are seeking to play a greater role. At the moment, EU and Japanese national standards bodies still hold the most leadership positions within ISO and IEC technical committees. In the rail sector, the secretariat for the ISO committee on railway applications (known as ISO/TC 269) is German, while the secretariat for the subcommittee for electrical equipment and systems for railways (known as IEC/TC 9) and the secretariats of ISO/TC 269 subcommittees on infrastructure and rolling stock are all French. The subcommittee secretariat for rail operations and services is Japanese. EU member states also chair the five Working Groups of IEC/TC 9.

CRRC and other Chinese rail firms are working to take on a bigger role in these and other SDOs, as they want to ensure their technology is the basis for future international standards.[357] Having their standards at the heart of international standards facilitates market access, advantages local products and firms, and leads to other firms paying them royalty fees for making products using the standard. For example, in 2018, CRRC stated it had hosted or participated in the drafting or revision of more than 70 international standards.[358] Most recently, in the CRRC's 2019 annual report, it stated that it had formulated and revised 12 international standards, among which it was the lead in 3.[359]

Canada, the EU, Japan, Korea, and the United States need to provide financial support and incentives to host SDO meetings in order to make it easier to facilitate local private sector participation. China and Chinese firms provide both significant funds and staff as a way of ensuring they are chosen to host, and participate in, as many meetings as possible. Foreign high-speed rail firms often find that for every engineer they send to an SDO meeting, CRRC will send several; and CRRC will not only pay annual membership fees for SDOs (which can cost tens of thousands of dollars a year), but provide additional funding for the SDOs to manage their operations and hold those meetings. Although remaining consistently engaged in SDO discussions is neither cheap nor easy, as it can be expensive for companies to assign one or several staff (such as engineers) to attend all the relevant meetings held throughout the world, other countries and firms need to employ this same strategy.

### Consider Allowing Rail Firms to Merge

To compete with the size and scope of CRRC, its foreign competitors have grown—or at least tried to grow—in scope and scale in order to be in a better position to compete. Competition authorities should take into account the state-sponsored nature of CRRC (and other Chinese rail firms) in considering, and allowing, mergers between rail firms.

In particular, Europe has failed to fully recognize CRRC's strategic and long-term impact on the global rail sector. On February 6, 2019, the European Commission blocked a merger of Siemens Mobility and Alstom on the grounds that the two companies have failed to address its concerns over the potential impact of the deal on competition in the signaling and high-speed rolling stock markets.[360] Siemens and Alstom remain, by far, the leaders for rail equipment in the EU market. However, their (understandable) fear of CRRC's growing global impact is clearly shaping their strategic planning, which is why the two companies sought to merge their train operations.

The European Commission opposed the merger due to misguided concerns about the impact such a merger could have on high-speed rail—stating that it would make Siemens and Alstom "the undisputed market leaders with a significant market share."[361] The European Commission competition authority's analysis of the global high-speed rail market basically disregards the impact China and CRRC have on the global high-speed rail market, as its market is largely closed to foreign competition, and the CRRC has not yet won a high-speed rail project in Europe.[362] CRRC is still the clear leader in the global high-speed rail market. And just because CRRC has yet to go head-to-head with Siemens and Alstom in Europe doesn't mean it has no desire to, or that the two firms won't be facing off against CRRC in pretty much every high-speed rail project elsewhere around the world in the future.

Just as the European Commission in large part attributes Siemens's and Alstom's leading positions to their roles as incumbent monopoly providers for their respective national operators (Deutsche Bahn in Germany and SNCF in France), it should realize that CRRC enjoys this same advantage (in a much larger market) and a lot more thanks to the huge financial and political support it receives from the Chinese government to build global market share in the future.[363]

The fact that Alstom and Siemens even considered such a merger reflects their recognition that their leading positions in Europe—and to a greater degree, their respective positions in other third-country markets—are tenuous.

Alstom, Siemens, Kawasaki, and other leading firms' management would be grossly incompetent if they acted as though China and CRRC did not matter to their respective abilities to compete and innovate in the future. CRRC and Chinese rail mercantilism is forcing rail firms around the world to find ways to protect themselves, such as by cooperating—or even merging—with their competitors. This is why, in February 2020, Alstom launched an acquisition of the railway unit of Bombardier in a $8.2 billion deal that created the world's second-largest rail firm, thus giving it greater economies of scale and scope to better compete with CRRC (see figure 3).

The new Alstom is the world's second-largest rolling stock manufacturer, with annual revenues of around $16.8 billion.[364] The deal merged Alstom's strength in high-speed rail with Bombardier's competitive advantage in subways and urban transit. After struggling to compete and be profitable in recent years, Bombardier had been pursuing a merger partner for some time.[365] Thankfully, the European Commission approved the deal, subject to conditions. French finance minister Bruno Le Maire saw the purchase as "good news for the European rail industry, which must remain at the forefront of innovation."[366] However, the European Commission required Alstom to divest Bombardier's assets that were part of its "Zefiro V300" high-speed platform with Hitachi. Alstom must also preserve the Bombardier-Hitachi consortium for the United Kingdom's HS2 project. Alstom also must divest several train production facilities in France and Germany.[367]

### Increase R&D Support and Coordination

Canada, Europe, Japan, the United States, South Korea, and other countries need to provide more funds as part of a long-term supportive R&D framework for rail firms. Europe has already taken many steps in the right direction, but there is no government-supported R&D framework for the rail sector in the United States.[368]

**Canada, the EU, Japan, and the United States should explore efforts to pool and leverage complementary innovation funds and initiatives at the international level.**

Encouraging greater innovation in the rail sector is challenging, as the long lifespans of rail products, such as locomotives and rail infrastructure, mean very long periods of time before firms see returns on their R&D investments. This makes rail R&D investment less appealing than in other sectors, such as motor vehicles. Similarly, the rail sector has suffered from a relative lack of innovation-related investments over the years (compared with the automotive and trucking sectors) as policymakers in many countries, for political reasons, continue to focus on road transport. As with other capital-intensive sectors, this highlights the importance of constant long-term investment in R&D to support the human capital and new equipment and manufacturing tools needed to help rail firms innovate. However, the ultimate success of these support programs depends on countries' ability to integrate them as part of holistic strategies that reward firms that are competing on innovation and performance, and penalize or exclude those that are competing on access to cheap financial subsidies and stolen IP.

Europe leads the way in showing what other countries could also do. But even still, it needs to commit greater amounts of coordinated research funding over the long term to truly support its rail firms. Europe also needs to do more to coordinate research priorities and shared initiatives—a coordinated approach to rail sector R&D other countries should emulate.[369] Indicative of this, the European Rail Research Advisory Council's (ERRAC) Rail Vision 2050 calls for significantly greater financial investment in R&D to maintain its current position and seize all the opportunities the next generation of rail technology has to offer.[370] The EU rail sector sees the European Commission's Horizon 2020 grants—the bloc's biggest R&D support program, with €80 billion available over seven years (2014–2020)—and national programs, such as tax discounts and low interest rate loans, as essential to ensuring constant investment in R&D.[371] The EU's Horizon 2020 research funding program included 182 references to rail projects.[372] In August 2020, the European Commission also called for public and private parties to become founding members of a new European Partnership on Rail Research and Innovation (to succeed in the Shift2Rail Joint Undertaking, which is the public-private partnership in the rail sector established under the EC's Horizon 2020 R&D and innovation plan).[373] Showing the growing focus on non-price factors involved in high-speed rail projects, the new Partnership's objectives are integrated with European Union policies toward the "European Green Deal's" objectives to shift a substantial part of the 75 percent of inland freight carried today by road to rail and inland waterways (transport accounts for one-quarter of the EU's greenhouse gas emissions).[374]

Canada, the EU, Japan, and the United States should explore efforts to pool and leverage complementary innovation funds and initiatives at the international level. At the heart of this joint approach would be a shared commitment by the countries to innovation-based competition, as opposed to China's use of unfair restrictions and subsidies to make their firms competitive. The EU should explore using Shift2Rail to cooperate with Canada, the United States, Japan, the United Kingdom, and others on joint research projects, especially if it can be integrated into procurement market access agreements. As the 2019 experts report on EU rail sector competitiveness states, facilitating this type of engagement and cooperation between respective firms, rail operators, and research institutions would help everyone ensure their research efforts are as effective as possible.[375]

## CONCLUSION

China's development of a nationwide network of high-speed trains surely could have spurred innovation in high-speed rail. But just as with the nation's approach to solar technology and its deployment, China could have played fair and used its large financial resources (including its massive trade surplus) to pay foreign firms for their products and technology, just like other countries do as part of rules- and comparative-advantage-based trade.[376] Doing so would have resulted in more innovative firms winning contracts, with China gaining even more resources to invest in innovation. And that would have benefitted the whole world. But alas, China took the mercantilist track.

China's unfair support for Chinese rail firms and products has reduced the market share, and thus the critical revenue, that drives R&D programs at the world's leading (non-Chinese) rail firms. The duplicative and inefficient R&D spending caused by China's artificial creation and support for CRRC and other Chinese firms detracts from research that is actually at the leading edge of innovation in the sector. In essence, China wants to artificially (and unfairly) create a high-tech economy—at the cost of innovation in the global high-speed rail sector. To be sure, this is not to say CRRC will not be able to catch up; it would be surprising if they didn't, given they have a massive protected domestic market. But the key question is whether there would have been more innovation had China not engaged in these policies—and the answer is yes.

For too long, policymakers around the world have turned a blind eye to China's mercantilist practices, often prioritizing short-term interests and low-cost products and projects over the long-term (and more disruptive) impacts the unfair and discriminatory policies behind these practices have on the broader sector, whether it is high-speed rail or any of the other sectors China's identifies as strategic. With innovation-intensive sectors such as high-speed rail, semiconductors, and biopharmaceuticals, once a leading country or firm loses this capability (through unfair competition or acquisition), it's nearly impossible to get it back. Whether foreign high-speed rail firms will be able to maintain their competitive edge in the global market in the future depends in no small part on whether policymakers enact changes to counteract and push back against CRRC and others' (mercantilist-supported) competitiveness.

**The key question is whether there would have been more innovation had China not engaged in these mercantilist policies—and the answer is yes.**

China's use of forced technology transfers for high-speed rail, like other strategic sectors China has targeted, also has broader trade, economic, and innovation implications beyond the rail segment.[377] For example, traction motors can be applied to subway systems, the bearings for bullet trains are similar to those used in wind turbines, and air suspension technologies in train bogies can also be used in bridges and other construction projects.[378] The value of China's use of mercantilist policies across sectors will likely end up being greater than those policies' individual parts as China reaps the economy-wide benefits of controlling and mastering such a broad range of technologies.

China's mercantilist approach to the high-speed rail sector shows that control is its overarching objective. Its explicit goal is to replace foreign firms and products at home and abroad. China's mercantilist strategy is not guaranteed to succeed in terms of mastering all key technologies involved in high-speed rail. It obviously lags behind the leaders in many areas, at the moment. But it is obviously willing to spend huge sums of money in inefficient, duplicative, and wasteful R&D and other spending in order to close the gap. However, whether the huge amounts of money China throws at the sector is wasteful is largely beside the point. As long as China's strategy is largely successful in speeding up the "leapfrog" process of creating large and technologically advanced Chinese firms, then it will be seen as a success. If this bankrupts or marginalizes foreign firms that otherwise lead (or would lead) innovation and competition in the sector, that's all the better. Chinese policymakers see no fault in their mercantilist approach as long as it contributes to China's economic, political, and national security goals.

There is little to no recognition in China that its approach is one-sided and detrimental to global innovation, and that ultimately its trading partners are well within their rights to react—perhaps even overreact—to make up for two decades of unfair economic policies, as Chinese firms seek to take advantage of their own open markets.[379] Foreign policymakers need to recognize that this is no longer just a trade issue its firms are facing in China, but a domestic economic one, as

Chinese firms enter their markets. Unless Canada, the EU, Japan, South Korea, the United States, and others push back, this market-distorting competition will push a range of local rail firms (not just in the high-speed segment) out of business, which, ironically, would leave them vulnerable to strategic acquisition by the same Chinese firms. Whether China gets away with this will depend on these countries finally taking much more aggressive actions to push back against Chinese rail sector mercantilism, while also doing more to support their own firms' ability to innovate and compete on fair and level terms both at home and in likeminded trading partners' markets.

## APPENDIX 1: KAWASAKI'S BATTLE TO KEEP AHOLD OF ITS TECHNOLOGY IN CHINA

The Kawasaki Heavy Industries-led consortium won a large part of China's initial 2004 high-speed rail contract, which required the consortium to transfer the full spectrum of technology and know-how for its iconic E2-1000 series Shinkansen bullet trains.[380] Its local partner was CSR Qingdao Sifang (a rolling stock manufacturer based in Qingdao, Shandong Province, that was a unit of CSR at the time). The Chinese company called its version of the train—which was capable of speeds up to 250 kph (155 mph)—the Hexie Hao (known as "Harmony" or the "CRH2"). China targeted high-speed rail technology from Kawasaki Heavy Industries because it wanted trains with motorization throughout each car, such as via EMU trains, which consist of self-propelled carriages. This contrasts with trains that have a separate locomotive, such as those provided by Alstom.

Kawasaki Heavy Industries would supply the first three finished trains plus the following six as knock downs for local assembly. After that, it would help the consortium's local Chinese partner produce 51 additional trains in China, using technology transferred by Kawasaki.[381] Kawasaki also had to develop the local supply chain for components and train Chinese engineers, including taking them to Japanese manufacturing facilities. At the same time, Kawasaki took dozens of CSR engineers to Japan for training, some of whom later helped set up the Qingdao factory, which now churns out about 200 trainsets a year. Over the ensuing years, China asked Kawasaki and others to provide additional technology to make its trains go even faster. Each time Kawasaki signed a deal, it earned several million dollars in fees, according to a senior Kawasaki executive.[382] By 2010, six years after the initial contract, at a time when Chinese firms had little to none of the technology required for high-speed trains, bullet trains were rolling out of Kawasaki's local partner CSR Qingdao Sifang's factory at a rate of more than two a week. In June 2011, China announced it had filed 21 international patent applications based on technology from Kawasaki Heavy Industries.[383]

Chinese officials are particularly indignant of China's high-speed trains being compared with Japan's Shinkansen bullet trains. The trains look identical to the E2-1000 models the Kawasaki consortium sold—under license—in 2004, but Mr. Luo Bin, vice-chief engineer at Sifang's Technology Development Centre, claimed that the technology underneath was completely different and indigenous, and that its latest models had "nothing at all to do with Shinkansen." He stated that within two years of the initial contract (2004 to 2006), CSR Qingdao Sifang had "digested" all the technology required to manufacture this highly complex and sophisticated piece of machinery.[384] Similarly, in state-run media, a MOR spokesman said, "The Beijing-Shanghai high-speed railway and Japan's Shinkansen cannot be mentioned in the same breath, as many of the technological indicators used by China's high-speed railways are far better than those used in Japan's Shinkansen."[385] At best, China has integrated the technology of its overseas partners without recognizing or paying for the right to do so. It certainly didn't leapfrog, it as it claimed.

According to experts, China's subsequent high-speed train model—the CRH380A, brought into service in 2010—was also based on the same technology as the Japanese bullet trains.[386] With the CRH380A, Chinese officials and train manufacturers (again) claimed that it was created solely from their own IP.[387] In a 2010 interview, Luo Bin said, "[The CRH380A] is an innovative design based on the technology we had already digested. This is completely the result of our autonomous design. It's got nothing to do with Bombardier or Siemens. It's got nothing at all to do with Shinkansen."[388] However, in a candid interview published in June 2011, Zhou Yimin, the former deputy director of MOR's high-speed department, admitted that the essential technology behind China's high-speed trains was foreign.[389]

According to Mr. Zhou, while the CRH380A-series trains should not be run faster than 300 kph, the rail ministry under former Minister Liu disregarded safety concerns and ran the trains at speeds of up to 350 kph. Mr. Zhou said the CRH380-series trains were able to go faster simply by "eating into the safety tolerances" of the originals.[390] A 2011 crash in Wenzhou between a CRH2 train and a CRH1 high-speed train (developed in a JV between Bombardier and CSR Sifang Locomotive and Rolling Stock Company) that killed 40 people should have provided a reason to pause.[391] It called into question the rush to develop and deploy indigenous technology.[392] Rather than buy a foreign-made high-speed rail system, the Chinese government insisted on building its own system—and it appears they lacked either the management or technical skills to build one up to international safety and performance standards.[393] However, it did not change China's commitment to mercantilist policies.

Foreign companies are reluctant to criticize the Chinese government, especially the powerful officials in charge of China's railways.[394] But Kawasaki, in a statement, called out China and disputed the claim that China created its own technology. Most of its trains in operation today, some executives say, are almost exactly the same as its foreign partner's trains, citing only a few tweaks to the exterior paint scheme and interior trims and a beefed-up propulsion system for faster speeds as the only differences from the original Shinkansen design.[395]

Kawasaki released statements saying it hoped to reach a resolution through commercial talks. During negotiations, Kawasaki emphasized that its technology-transfer contracts with MOR state that the technology is for use exclusively within China, and that Chinese companies can't use it in products they intend to export.[396] As one unnamed senior executive at Kawasaki told the media, "Claiming most of the recently developed bullet trains as China's own may be good for national pride... but it's nothing but deceitful propaganda. How are you supposed to fight rivals when they have your technology, and their cost base is so much lower[?]"[397] Not surprisingly, in hindsight, some executives questioned the wisdom in dealing with China in the first place. In 2010, Yoshiyuki Kasai, then-chairman of Central Japan Railway Co. (which operates Shinkansen trains in Japan), stated, "We didn't take part in the export project to China … The conditions were not favorable—they wanted all the technology to be transferred for free. That was not good for us."[398]

## APPENDIX 2: CRRC'S GROWING ROLE IN EUROPE'S RAIL MARKET

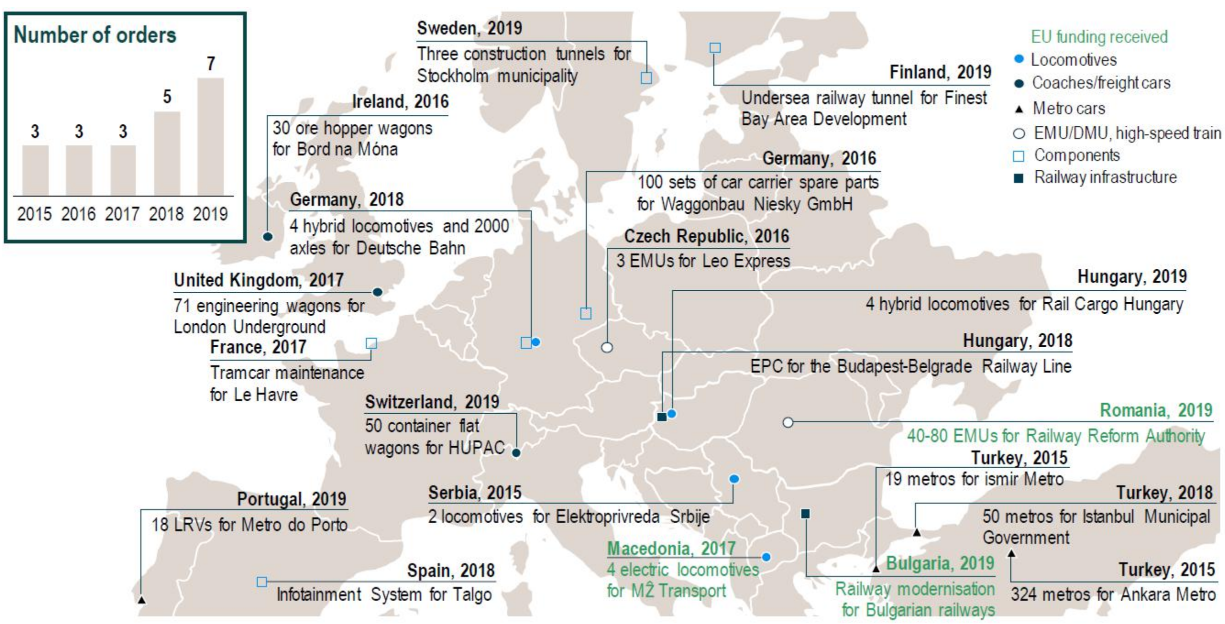
CRRC and other Chinese rail firms clearly have designs on growing their market share in Europe's rail market, which is one of the largest in the world. However, it is also one of the more challenging markets to enter, given it is already home to a range of local and foreign rail firms that have proven themselves highly capable in delivering rail products and projects. It is also challenging because of local performance and technical standards and the role of national and regional authorities (however, it's still a much more open market than China's). This annex analyzes CRRC and other Chinese rail firms' successes, and setbacks—showing parts of their strategy and growing efforts to seize market share in Europe.

CRRC's internationalization strategy involves direct exports, with Chinese financing wherever possible. Elsewhere, it involves setting up local factories, mainly to assemble imported components from China, to abide by local content requirements for procurement contracts. It often uses these factories and initial contracts to gain a foothold in a market, with the goal of gaining formal acceptance and local certifications and approvals to compete for new contracts and projects. While the majority of CRRC's international projects and sales are in other (non-high-speed) segments of the rail market, they still help build CRRC's broader competitiveness, which it uses to support high-speed rail sales whenever these projects arise.

CRRC's entry into Europe is indicative of its broader strategy of learning how to compete in developed markets—because doing so means it can essentially learn to successfully compete in any market (when allowed). First, CRRC targets small-scale procurement projects. Then, after gaining experience and accreditation, it begins to target larger and more-sophisticated and higher-value contracts, moving from freight to light rail and metro to large and fast passenger trains, before working toward its ultimate goal of entering the high-speed rail segment. In addition, local contracts and acquisitions (not necessarily in the high-speed rail segment, but associated sectors) allow CRRC to learn and integrate the required know-how about procurement processes, how to adapt and make products to European norms and standards, and how to engage local regulators.

In Europe, this strategy started with CRRC and other Chinese rail firms targeting, and ultimately winning, projects in both Western and Central Europe (see figure 21). Those contracts were often supported by government-to-government memorandums of understandings. CRRC has since won contracts in the United Kingdom, Germany, Switzerland, and Portugal.

**Figure 21: Map of Europe with significant orders won by Chinese enterprises (2015–2019)[399]**




CRRC's efforts to get a foothold in the EU high-speed rail market has had some success, but also the odd setback. As to the latter, in 2017, CRRC was interested in (but was not invited) to bid on the $3.6 billion contract for the United Kingdom's high-speed rail project HS2.[400] Among its successes, in 2016, CRRC signed a $20.9 million agreement with Czech railway company Leo

Express for three high-speed trains. The deal was the first foreign project to use Chinese high-speed trains (operating at 160 kph, the maximum allowed on Czech railways) in the EU.[401] The trains were scheduled to be delivered by mid-2018, but didn't actually arrive until September 2019. The trains only included 20 percent local (Czech) content.[402] Today, the trains remain out of service until they pass EU standards and certification testing.[403] In 2020, the Czech Republic stated that it was moving ahead with plans to develop a bigger and higher-speed rail network (300–350 kph).[404] CRRC no doubt wants to play a role in this expansion.

China's first major high-speed rail project in Europe—the Belgrade-to-Budapest high-speed rail line—is indicative of China's growing ambitions, but also the challenges it faces in winning and executing contracts. Initially, Hungary's government bypassed the EU's mandatory competitive bidding process to directly issue a contract to the Chinese firm for the infrastructure component of the $2.89 billion project. However, after pressure from the European Commission, the Hungarian government issued a tender, albeit one tailored for the leading Chinese-Hungarian JV set up for the project, which ultimately won the bid.[405] Hungary's government has since classified details of the contract. China's Ex-Im bank is financing 85 percent of the project with a 20-year, $1.9 billion loan (with a 2.5 percent interest rate).[406]

At the Serbian end of this high-speed rail line, China's Ex-Im bank provided a $297 million loan to help Serbia cover its part (around $2 billion) of the project.[407] A Chinese consortium then won the contract and began work on this end of the project in November 2017. The initial work raised concerns in the EU rail sector, as the signaling part of the project explicitly accepted Chinese and EU testing standards. Indicative of how it views the strategic value of the project, CRSC established a laboratory in Belgrade to provide train operation control systems for the high-speed trains on the Hungary-Serbia railway. This was significant, as it is the first laboratory for high-speed train operation control systems to be built overseas by a Chinese company.[408] In July 2020, Serbia announced that the Chinese firm CRBC had been selected as part of early plans to build another (an estimated €2billion) high-speed rail line, between Belgrade and Nis (the country's third-largest city).[409]

Similarly, CRRC's pursuit of Bulgaria's railway modernization project (which uses both Chinese and EU funds) is further evidence of its strategy to use public procurement projects to get a foothold in the EU rail market. In EU rail projects, firms typically must include a reference project to show they're able to abide by EU signaling, electrification, and other standards. However, this Bulgarian project didn't require such a reference, so CRRC will be able to use this project as a reference in future bids on other rail projects to show that it can abide by EU technical requirements. Essentially, CRRC was able to get this critical reference for cheap—and with EU funds. This could be a landmark project for CRRC, as it allows the company to enter the signaling market, which it thus far hasn't been able to.

CRRC's pursuit of metro rail contacts—many of which involve EU funding—is indicative of its efforts to compete in all segments of the European rail market. In December 2019, CRRC won a €56 million contract to supply 18 light rail vehicles to the Porto Metro (the public transport system of Porto, Portugal). The extension of this project was financed by the EU Cohesion Fund.[410]

Meanwhile, CRRC projects in Romania have brought the various factors together: underbidding, benefiting from EU funds, and a procurement assessment process that does not factor in abnormally low bids and market-distorting state aid and subsidies. In 2019, CRRC won a €357 million–€957 million contract for 40 to 80 electric regional trains in Romania. It underbid Alstom and Siemens by 25 percent.[411] The contract assessment criteria was heavily weighted on price (80 percent). CRRC was also a direct beneficiary of the EU funds involved in the project (the EU's Large Infrastructure Operational Programme).[412]

Another contract in Bucharest provides an additional demonstration of CRRC's commitment and persistence in working to gain a foothold in the EU rail market. In September 2020, a CRRC-led consortium of Chinese and Romanian firms won a €172.9 million Bucharest council bid for 100 trams.[413] Again, CRRC was a direct beneficiary of EU funds (EU Cohesion Funds). This followed an earlier legal dispute whereby CRRC challenged the initial awarding of the contract to a Turkish company (Durmazlar), which scored 99.6 (out of 100) for tender criteria. For quality criteria, Durmazlar scored 39.61 to CRRC's 35.90, while for price criteria, Durmazlar somehow managed to be equally competitive with a score of 60 (compared with CRRC's 59.85).[414] Yet, CRRC still somehow managed to win the appeal, and the contract.

## APPENDIX 3: CRRC AND OTHER CHINESE RAIL FIRMS' GLOBAL ACQUISITIONS TO ACCESS RAIL TECHNOLOGY AND MARKETS

Chinese firms and the Chinese government are going out into the world in search of strategic high-speed rail technology acquisitions.[415] Chinese academic Luo Qin summarized China and CRRC's strategy: "With product life cycle changes, and without product innovation, China CRRC will be replaced sooner or later. So technology acquisition is still one of the reasons for internationalization."[416] Foreign acquisitions also provide quicker access to regulatory approvals and certifications. The president and owner of Stadler Rail—one of the leading manufacturers of railroad vehicles in Europe, next to Alstom, Bombardier, and Siemens—Peter Spuhler, stated (after a visit by CRRC), "There are only about 10 companies left in railway vehicle production in Europe. If the Chinese want to crack European markets, they need a basis here that will enable them to manage the national approval processes."[417]

Below is a list of key foreign acquisitions (in chronological order):

- In 2008, a CRRC subsidiary acquired a 75 percent stake in Dynex power (United Kingdom) to master state-of-the-art insulated-gate bipolar transistor technology (used as an electronic switch), which is central to developing high-speed trains operating over 350 kph. It also established a leading high-power semiconductor R&D center in the United Kingdom.[418]
- In 2011, a CRRC subsidiary acquired Delkor Rail (Australia) to enhance its competitiveness utilizing Delkor's R&D capability in track shock-absorber products. CRRC now uses Delkor to enter other foreign markets and projects, such as for the London Underground.[419]
- In 2013, a CRRC subsidiary acquired the rubber & plastics division (BOGE Programme) of the German firm ZF Friedrichshafen AG (also known as the ZF Group). The acquisition included 10 global production centers and 4 R&D centers. BOGE Programme's technology is central to helping the subsidiary—Zhuzhou Times New Material Technology Co., Ltd. (TMT)—become the world's leading supplier of vibration technology and polymer composite materials in the railway field.

- In 2014, Chinese firm Maanshan Iron and Steel—the world's biggest manufacturer of forged wheels for rolling stock—acquired Valdunes (France) in order to improve its wheel design and manufacturing for high-speed trains. This included R&D centers in Dunkirk and Valenciennes in France.[420] The acquisition leaves only a handful of other firms that make specialized wheels for high-speed trains.
- In 2015, CRRC tried (but failed) to acquire the Czech Republic's Skoda Transportation, which would've provided a major entry point into Europe's rolling stock market.[421] Skoda exports more than 50 percent of its production to the EU and U.S. markets. The potential €2 billion acquisition was to be confirmed during the Czech-Chinese Investment Forum in Prague in July 2017, but was never formally approved. In 2016, China CEFC Energy Company, together with the Beijing Municipal Road and Bridge Group, bought 80 percent (€240 million) of the Czech company TSS Cargo, which is the largest Czech railway operator.[422]
- In 2016, CRRC acquired Cideon Engineering (Germany and Switzerland) for €14.6 million. Cideon is a small, specialty engineering and software company that is involved in rail vehicle design and engineering. It is also well versed in Europe's complex licensing procedures.[423]
- In 2020, CRRC acquired Vossloh Locomotives (Germany), which was the market leader for short-distance diesel locomotives. While Vossloh's diesel locomotives are a shrinking market segment, as electric locomotives become more important, the acquisition by CRRC provided a major foothold in the European rail market, as Vossloh had 25 percent of the diesel-locomotive market. The acquisition gave CRRC all the standards and technology required to bring its trains quicker onto European railway tracks.[424] German competition authorities reviewed, and ultimately approved, the acquisition despite protests from other EU rail firms that it would distort the market in the future and EU firms had little or no reciprocal investment or market access in China.[425] Despite the firm's state subsidies and other strategic advantages (in terms of standards and technology), German competition authorities still approved it, as Vossloh was otherwise struggling to compete.[426]

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## ENDNOTES


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250. Ibid.

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253. Ibid.

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258. Gruley, "How To Stop A Speeding Train."

259. UN Comtrade Dataset, Locomotive and rolling stocks (code 86 Railway or tramway locomotives, rolling stock and parts thereof; railway or tramway track fixtures); European Commission, *Study on the competitiveness of the rail supply industry.*

260. UNIFE, "Briefing for the Estonian Presidency of the Council of the European Union" (Industry Paper, July 2017), https://www.unife.org/component/attachments/attachments.html?id=835&task=download.

261. European Commission, *Report of the expert group on competitiveness of the European rail supply industry.*

262. Ibid.

263. For example, OECD's statistics on business enterprise R&D expenditure by industry is the only potential source of comprehensive data for R&D investments by the rolling stock and locomotive sector. However, the data is inconsistent and there was a classification change that affected what countries report, and it doesn't include China. Its classification may also not fully correspond with the R&D sector definition that is used in firms' annual reports. For a comparison of 2011–2015 for some countries, see table 38 on page 122 of European Commission, *Study on the competitiveness of the rail supply industry.*

264. Which is for the broader transportation sector.

265. See endnote 264. The breakdown between industries follows the "International Standard Industrial Classification of all Economic Activities" (i.e., the ISIC classification). Therefore, data can only be provided for the ISIC Rev. 4 30.20 - Manufacture of railway locomotives and rolling stock. European Commission, *Study on the competitiveness of the rail supply industry;* "Sector Overview and Competitiveness Survey of the Railway Supply Industry Within the Framework Contract of Sectoral Competitiveness Studies – ENTR 06/054" (Report prepared by Ecory's for the European Commission, May 2012), https://ec.europa.eu/growth/content/study-sector-overview-and-competitiveness-survey-railway-supply-industry-0_en.

266. Ana Maria Santacreu and Heting Zhu, "What Does China's Rise in Patents Mean? A Look at Quality vs. Quantity," Post from the Economic Research unit of the Federal Reserve Bank of St. Louis, 2018, https://research.stlouisfed.org/publications/economic-synopses/2018/05/04/what-does-chinas-rise-in-patents-mean-a-look-at-quality-vs-quantity/; Lulu Yilun Chen, "China Claims More Patents Than Any Country—Most Are Worthless," *Bloomberg,* September 26, 2018, https://www.bloomberg.com/news/articles/2018-09-26/china-claims-more-patents-than-any-country-most-are-worthless; Josh Ye, "Chinese government subsidies fuel surge in patents but experts warn it's quantity over quality," *South China Morning Post,* April 15, 2020, https://www.scmp.com/tech/enterprises/article/3079878/chinese-government-subsidies-fuel-surge-patents-experts-warn-its.

267. Ibert G.Z. Hu, Peng Zhang, and Lijing Zhao, "China as number one? Evidence from China's most recent patenting surge," *Journal of Development Economics*, vol. 124 (2017): 107–119, https://doi.org/10.1016/j.jdeveco.2016.09.004.

268. For example, CRRC's annual reports state the importance of intellectual property and how many domestic patents it receives—from 741 in 2010, 1748 in 2013, 1,769 in 2014, and 2,497 in 2018. However, CRRC does not specify in its annual reports how many patents are held in other countries, which would otherwise act as a proxy for whether its patents in China are of lower quality (as there are government-provided financial incentives for firms to apply for patents).

269. According to PATSTAT, 187,642 patents have been granted worldwide between 2011–2017 under the International Patent Classification "B61-Railways." Most of them were granted by the Chinese authority (i.e., The National Intellectual Property Administration), followed by the USPTO – US Patent and Trademark Office (17.873), KIPO - Korean Intellectual Property Office (8.587) and JPO - Japan Patent Office (8.088). European Commission, *Study on the competitiveness of the rail supply industry*.

270. PR-intensive industries are defined as those having an above-average use of IPR per employee EPO & EUIPO (2013). This analysis is limited to the total railway supply industries due to the specification of the industry thought NACE codes. The EPO/EUIPO study does not categorize NACE 33.17 "Repair and maintenance of other transport equipment" as an IPR intensive industry. Therefore, the analysis focuses only on NACE 30.20 "Manufacture of railway locomotives and rolling stock."

271. From its English language annual reports.

272. Data taken from each firm's annual reports. CRRC's figures start in 2015 given that was the year CNR and CSR merged.
273. The list was drawn from the 10 firms used in the European Commission Study on the competitiveness of the rail supply industry: European Commission, *Study on the competitiveness of the rail supply industry.*
274. The list of the top 10 firms was taken from the European Commission Study on the competitiveness of the rail supply industry. R&D and revenue figures were taken from the firm's annual reports. CRSC data was from 2018 (that latest available). Where possible, data was from the relevant transport division, such as with the Siemens Mobility Division and Caterpillar's energy and transportation division. European Commission, *Study on the competitiveness of the rail supply industry.*
275. CRRC annual reports. The Alstom data is an estimate, as the website said that it had greater than 7,000 R&D employees. "Innovation drives our growth," Alstom website, accessed March 23, 2021, https://www.alstom.com/company/innovation; "Employees of Alstom from 2015/16 to 2019/20," *Statista*, https://www.statista.com/statistics/1178129/alstom-employees-worldwide/.
276. Ibid.
277. "Sector Overview and Competitiveness Survey of the Railway Supply Industry Within the Framework Contract of Sectoral Competitiveness Studies – ENTR 06/054."
278. Taken from firm annual reports.
279. Santacreu and Zhu, "What Does China's Rise in Patents Mean? A Look at Quality vs. Quantity;" Chen, "China Claims More Patents Than Any Country—Most Are Worthless;" Ye, "Chinese government subsidies fuel surge in patents but experts warn it's quantity over quality."
280. PATSTAT is one of the most widely used patent databases for researchers. It includes patent details from around the world. Disclaimer: this represents a mere count, as the authors of the original study did not group patents by patent families (i.e., the same invention disclosed by a common inventor(s) and patented in more than one country). Under the International Patent Classification, "B61-Railways" is divided in nine subgroups, which include: systems in which trains or individual passenger vehicles or load carriers run on, or are guided by, ground or elevated tracks defined by rails, ropes, cables, or other guiding elements for wheels, rollers, or sliding anti-friction devices; systems in which carriers or impellers for persons or loads are attached to, e.g., suspended from, a guided traction rope or cable which determines their path of movement; power and free systems of either of the above types in which vehicles, load-carriers, or loads may be selectively coupled to, or uncoupled from, continuous traction members, e.g., cables, chains. Database: https://inspire.wipo.int/patstat-online. The attribution of a patent to a particular entity is challenging. For example, there may be a spelling mistake and many companies are known under several different names. The European Commission report authors clearly state this in their analysis. Graph and data from: European Commission, *Study on the competitiveness of the rail supply industry.*
281. Voith, Knorr Bremse, and Hubner Group are all rail component providers. At the firm level, Siemens had the most with 373—which could actually be non-rail patents (hence its exclusion from figure 13, as Siemens Mobility only accounted for 7–15 percent of total revenue between 2013 and 2019).
282. The EPO is not legally bound to the EU. Patents can also be granted by Member States' patent authorities individually, which only have validity within the border of their jurisdiction. For example, the Spanish patent authority granted 1,498 patents, the German patent authority granted 1,043 patents, and the French patent authority granted 1,027 in the period 2011–2017. Data and analysis drawn from: European Commission, *Study on the competitiveness of the rail supply industry.*

283. Patent Statistics Database (PATSTAT), accessed March 23, 2021, https://data.epo.org/access-control/patstatsubscription.jsp; also see the explanation in endnote 281.

284. "EXTENDED YEAR SET - Patenting In Technology Classes, Breakout By Organization, Class 104, Railways," USPTO website, accessed March 23, 2021, https://www.uspto.gov/web/offices/ac/ido/oeip/taf/tecasga/104_torg.htm; "EXTENDED YEAR SET - Patenting In Technology Classes, Breakout By Organization, Class 105, Railway Rolling Stock," USPTO website, accessed March 23, 2021, https://www.uspto.gov/web/offices/ac/ido/oeip/taf/tecasga/105_torg.htm.

285. Patent Statistics Database (PATSTAT), accessed March 23, 2021, https://data.epo.org/access-control/patstatsubscription.jsp, and ITIF Internal Calculations.

286. Innography's data sources include patents of more than 90 countries and regions, more than 80 million global patent data, business data, U.S. patent litigation, and U.S. business standard data. Huaqing Tang and Helin Yang, "Analysis of Patent Information of Supercapacitor Based on Innography," *2018 International Conference on Robots & Intelligent System* (ICRIS), Changsha, China (2018): 321–325, doi: 10.1109/ICRIS.2018.00087.

287. When the authors did their search of Innography.

288. Zin Liu and Xi Yang, "Identifying Technological Innovation Capability of High-Speed Rail Industry Based on Patent Analysis," *2019 8th International Conference on Industrial Technology and Management (ICITM)*, Cambridge, UK (2019): 127-131, doi: 10.1109/ICITM.2019.8710710.

289. Ibid.

290. Ibid.

291. F. Zhang and X. Zhang, "Patent activity analysis of vibration-reduction control technology in high-speed railway vehicle systems in China," *Scientometrics*, 100 (2014): 723–740, https://doi.org/10.1007/s11192-014-1318-3.

292. In January 2004, the State Council passed the ''Chinese Medium- and Long-Term Plan of Railway Network."

293. The study used State Intellectual Property Office of the People's Republic of China and the World Intellectual Property Organization (WIPO) PCT database. It found 193 patents (as at 2011). A three-step search strategy was used: first, to retrieve SIPO patent data by patent title or abstract containing "rail*," "vibration," and "reduction/attenuation/control/damping" and by IPC containing "B61*." Second, to remove those invented technologies that are limited to freight trains and locomotives or slower-moving passenger trains and locomotives by reading the patent titles and abstracts. Third, to read the patent specifications and to reject patents where the invented technology is restricted to operating speeds of <200 kph. Zhang and Zhang, "Patent activity analysis of vibration-reduction control technology in high-speed railway vehicle systems in China."

294. Ibid.

295. Which can be characterized by whether it has an engine (motor bogies, track bogies), the number of axes (e.g., two-axis, three-axis and multi-axis bogies), or by axial positioning (e.g., pull-type, rod-type, arm-type, laminated, and dry friction bogies).

296. Xiaojun Deng et al., "European high-speed bogie technology review," *International Journal of Vehicle Design (IJVD),* vol. 79, no. 1 (2019), http://www.inderscience.com/offer.php?id=101520.

297. Bingxiu Gui, Yanbing Ju, and Yun Liu, "Mapping technological development using patent citation trees: an analysis of bogie technology," *Technology Analysis & Strategic Management* 31:2 (2019): 213–226, doi: https://www.tandfonline.com/doi/full/10.1080/09537325.2018.1493190.

298. Ibid.

299. The study used the search parameters: @(abstract, claims, title) [(electromagnetic* or magnetic*) and (levitat* or suspen*) or maglev or EML] and (rail* or trans* or train* or vehicle) @* and (ipc_B60 or ipc_E01 or ipc_B61).

300. Jinsong Gou, "Development Status and Global Competition Trends Analysis of Maglev Transportation Technology Based on Patent Data," *Urban Rail Transit* 4 (2018): 117–129, https://doi.org/10.1007/s40864-018-0087-3.

301. 3,360 patents, which is 27.1 percent of all patents.

302. In China, maglev patent rose from 8 in 1998 to 663 in 2016. Gou, "Development Status and Global Competition Trends Analysis of Maglev Transportation Technology Based on Patent Data."

303. Ibid.

304. Ibid.

305. Ibid.

306. Ibid.

307. Ibid.

308. Ibid.

309. Ibid.

310. The Innography platform contains a patent-mining capability. Using the results of research on patent value determination conducted by the University of California, Berkeley, George Mason University, Stanford University, and the University of Texas, Innography divides the strength of patents into three levels: A patent with a strength indicator value equal to or greater than 80 percent is considered a core patent; a patent with an indicator between 30 and 80 percent is considered an important patent; and a patent with an indicator less than 30 percent is considered a general patent.

311. In 2002, China reportedly invested nearly $6.3 billion in the high-speed market in which foreign companies competed—carriages, signaling equipment, and other high-tech track components—and foreign companies captured about 70 percent. In 2010, China invested an estimated $23 billion in the segment, of which foreign companies only accounted for an estimated 15 to 20 percent, earning roughly the same as in 2002. Anderlini and Dickie, "China: A future on track."

312. EPO patent data would have been useful to also include, but its user interface makes it difficult to identify rail-specific patents for individual firms.

313. ITIF internal calculations.

314. As a blanket rule, countries should initiate a subsidy review for all acquisitions from non-market-based, innovation-mercantilist economies, such as China's. China itself refuses to abide by its WTO commitments about subsidy disclosure, so it's up to each country's foreign investment screening authority. Reviews should ascertain the actual source of funding, as subsidies can be provided indirectly and are hard to track. For example, as in semiconductors, subsidies are sometimes presented as private venture capital investments, when in fact they are government-funneled money channeled through an intermediary to hide the fact that it's really a government subsidy. USTR, *2019 Report to Congress On China's WTO Compliance*.

315. For a summary of these, see: Nigel Cory and Robert Atkinson, "Why and How to Mount a Strong, Trilateral Response to China's Innovation Mercantilism" (ITIF, January 2020), https://itif.org/publications/2020/01/13/why-and-how-mount-strong-trilateral-response-chinas-innovation-mercantilism; "Foreign Investment Risk Review Modernization Act: Title XVII," U.S. Department of Treasury website, accessed March 23, 2021, https://home.treasury.gov/sites/default/files/2018-08/The-Foreign-Investment-Risk-Review-Modernization-Act-of-2018-FIRRMA_0.pdf; James K. Jackson, "The Committee on Foreign

Investment in the United States (CFIUS)" (Washington, D.C.: Congressional Research Service, August 6, 2019), https://fas.org/sgp/crs/natsec/RL33388.pdf.

316. "European Parliament resolution of 23 May 2012 on EU and China: Unbalanced Trade? (2010/2301(INI))," European Parliament website, May 23, 2012, http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P7-TA-2012-0218+0+DOC+XML+V0//EN; Yann Le Guernigou and Leigh Thomas, "France, Germany, Italy urge rethink of foreign investment in EU," *Reuters*, February 14, 2017, https://www.reuters.com/article/uk-eu-trade-france-idUKKBN15T1ND?il=0; Angela Stanzel, "Germany's turnabout on Chinese takeovers Commentary," *European Council on Foreign Relations*, March 21, 2017, https://www.ecfr.eu/article/commentary_germanys_turnabout_on_chinese_takeovers_7251.

317. "Competition authority clears CRRC acquisition of Vossloh Locomotives," *Railway Gazette International,* April 27, 2020, https://www.railwaygazette.com/business/competition-authority-clears-crrc-acquisition-of-vossloh-locomotives/56367.article.

318. It noted that CRRC had supplied some shunters to Deutsche Bahn in Hamburg and Berlin and to Rail Cargo Hungaria, but that its success in Europe "has been limited so far." Ibid.

319. For example, the EU should ensure member states set a general minimum (de minimis) threshold for investigations of foreign investments, but it should cover all acquisitions involving China and be flexible so as to include smaller specialist firms. China provides significant subsidies to small, technology-focused start-ups, including subsidized venture investments in them, as a way to help them acquire firms to gain access to emerging technologies. These can be very distortive and harmful. Robert Atkinson, "Response to the European Commission's Consultation on Its White Paper on Foreign Subsidies" (ITIF, submission to the European Commission, September 6, 2020), http://www2.itif.org/2020-consultation-foreign-subsidies.pdf?_ga=2.25753150.289336247.1602611839-254668983.1577993982.

320. "New EU framework for screening FDI into the EU," Baker McKenzie website, April 15, 2019, https://www.bakermckenzie.com/en/insight/publications/2019/04/new-eu-framework-for-screening-fdi-into-the-eu.

321. Ironically, in 2016, Volker Schenk (a board member of Vossloh, which was acquired by a Chinese firm, see annex 2) stated, "We needn't fear the Chinese when it comes to technology." But he called for "fair underlying conditions" because, "as a state-owned company, CRRC has access to inexhaustible financial means." Dieter Fockenbrock, "China's Rail Giants on a European Tour," *Handelsblatt,* April 26, 2016, https://www.handelsblatt.com/english/companies/train-takeovers-chinas-rail-giants-on-a-european-tour/23537504.html?ticket=ST-3125065-n3kaHwI1dIDCVEB2MdQz-ap5.

322. Daniel Michaels and Drew Hinshaw, "Chinese Companies Win Billions in European Taxpayer-Funded Contracts," *Wall Street Journal,* December 17, 2020, https://www.wsj.com/articles/chinese-companies-win-billions-in-european-taxpayer-funded-contracts-11608222716.

323. Jim Kenney, "CRRC MA, Rep. Richard Neal celebrate victory in Washington; compromise allows rail car company to keep seeking new work," *Mass Live,* December 23, 2019, https://www.masslive.com/business/2019/12/crrc-ma-rep-richard-neal-celebrate-victory-in-washington-compromise-allows-rail-car-company-to-keep-seeking-new-work.html.

324. For example, given EU member states retain a lot of control over public procurement, it recommends that the European Commission work with member states to develop and share best practices in implementing procurement provisions to excluded abnormally low bids and firms that benefit from market-distorting foreign state aid and subsidies. European Commission, *Report of the expert group on competitiveness of the European rail supply industry*.

325. These requirements encouraged industry players to propose high standards in terms of innovation and environmental sustainability during the tender process.

326. European Commission, *Study on the competitiveness of the rail supply industry.*

327. The MEAT principle enables the contracting authority to take account of criteria that reflect qualitative, technical, and sustainability aspects as well as price.

328. UNIFE, "Briefing for the Slovak Presidency of the European Union" (Industry report, July 2016), https://www.unife.org/component/attachments/attachments.html?id=703&task=download.

329. "Communication from the Commission: Guidance on the participation of third-country bidders and goods in the EU procurement market (2019/C 271/02)" (Official Journal of the European Union, C271/44, August 13, 2019), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC0813(01)&from=EN.

330. Ibid.

331. European Commission, *Study on the competitiveness of the rail supply industry.*

332. European Commission, *White paper on levelling the playing field as regards foreign subsidies* (Brussels: European Commission, June 17, 2020), https://ec.europa.eu/competition/international/overview/foreign_subsidies_white_paper.pdf; European Commission, "Commission adopts White Paper on foreign subsidies in the Single Market," press release, June 17, 2020, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1070.

333. European Commission, "Commission reviews relations with China, proposes 10 actions," press release, March 12, 2019, https://ec.europa.eu/commission/presscorner/detail/en/IP_19_1605.

334. China is not, and is unlikely to be, transparent about its subsidies, so in cases where a foreign company is not forthcoming and transparent, or delays and obfuscates, the European Commission should be allowed to assume the presence of problematic subsidies. Atkinson, "Response to the European Commission's Consultation on Its White Paper on Foreign Subsidies."

335. This would likely be transversal (as in module 1 of the foreign subsidy white paper), which could consider several tenders as part of the investigation. European Commission, *White paper on levelling the playing field as regards foreign subsidies*.

336. "European Parliament resolution of 9 June 2016 on the competitiveness of the European rail supply industry (2015/2887(RSP))," European Parliament, June 9, 2016, https://www.europarl.europa.eu/doceo/document/TA-8-2016-0280_EN.html.

337. Similar to the Government Procurement Agreement (GPA) and government procurement commitments in free trade agreements (FTAs), the IPI does not affect the GPA or EU trade agreements that deal with public procurement. It aims to provide a new way to encourage trading partners to engage in negotiations and open participation for bidders and goods in each other's tendering procedures and to provide new remedies for affected firms. Importantly, an IPI would allow the EU to initiate public investigations when EU companies are discriminated against in foreign markets. If this is proven, the European Commission would initiate consultations with the foreign country. However, if this doesn't lead to changes, the European Commission is considering allowing local authorities to explicitly exclude subsidized bidders from competing and allowing them to enact a price-adjustment measure to subsidized bids. As to the latter, the contracting authority could apply a price penalty to bids from the targeted country. Thus, the IPI allows the European Commission to take proportionate and targeted action in cases of alleged discrimination against European companies in the procurement markets of other countries and against bids that benefit from market-distorting subsidies. However, the future of the IPI is uncertain as some key EU member countries (most notably, Germany) remain divided on if and how to respond to state-subsidized firms. Also see: "Legislative Train Schedule: A balanced and progressive trade policy to harness globalization," European Parliament, http://www.europarl.europa.eu/legislative-train/theme-a-balanced-and-progressive-trade-policy-to-harness-globalisation/file-international-procurement-

instrument-(ipi); "International public procurement," European Commission, https://ec.europa.eu/growth/single-market/public-procurement/international_en.

338. "Communication from the Commission — Guidance on the participation of third-country bidders and goods in the EU procurement market C/2019/5494," European Union, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019XC0813(01).

339. World Bank, "China's Experience with High Speed Rail Offers Lessons for Other Countries," press release, July 8, 2019, https://www.worldbank.org/en/news/press-release/2019/07/08/chinas-experience-with-high-speed-rail-offers-lessons-for-other-countries.

340. The closest it has come was mentioning it in comments about China's efforts to become as "self-sufficient as possible." Martha Lawrence, Richard Bullock, and Ziming Liu, *China's High-Speed Rail Development* (Washington, D.C.: World Bank, 2019), http://documents1.worldbank.org/curated/en/933411559841476316/pdf/Chinas-High-Speed-Rail-Development.pdf.

341. As the World Bank states, "[T]his collaboration allowed China to introduce, digest, absorb, and re-innovate foreign advanced electric multiple unit technology in a short period of time to create a successful product." The World Bank's broader engagement with China only touches upon the issue in the joint World Bank and Development Research Center of the State Council report, which states that "it is in China's interests to provide the legal and institutional framework to prevent 'forced' technology transfers and to encourage the introduction of foreign technologies in China." Ibid; World Bank and the Development Research Center of the State Council, the People's Republic of China, "Innovative China: New Drivers of Growth" (Washington, D.C.: Joint report, 2019), http://documents1.worldbank.org/curated/en/833871568732137448/pdf/Innovative-China-New-Drivers-of-Growth.pdf.

342. Kratz and Kingley, *Leveraging the Chinese State Against Foreign Firms: Rail and Beyond.*

343. World Bank, "World Bank Group Debars China Railway Construction Corporation Ltd. and two subsidiaries," press release, June 5, 2019, https://www.worldbank.org/en/news/press-release/2019/06/05/world-bank-group-debars-china-railway-construction-corporation-ltd-and-two-subsidiaries.

344. European Commission, "EU and 10 other members suspend participation in negotiations in the International Working Group on Export Credits," press release, November 19, 2020, https://trade.ec.europa.eu/doclib/press/index.cfm?id=2214; Kamala Dawar, "Regulating under the radar: EU official export credit support," *VoxEU*, January 31, 2020, https://voxeu.org/article/eu-official-export-credit-support-0.

345. U.S. EXIM Bank, *Report to the U.S. Congress on Global Export Credit Competition* (Washington, D.C.: U.S. EXIM, June 2020), https://www.exim.gov/sites/default/files/reports/competitiveness_reports/2019/EXIM_2019_CompetitivenessReport_FINAL.pdf.

346 Ibid.

347 Ibid.

348. Japan Bank for International Cooperation (JBIC) is not considered an official export credit agency (as it's not necessarily used to support Japanese exports). "Introduction of JBIC and its Financing for the Railway Projects" (JBIC presentation, February 3, 2017), http://pubdocs.worldbank.org/en/858151486603954225/20170209-Introduction-of-JBIC-and-its-Financing-for-the-Railway-Projects.pdf.

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tech maritime vessel manufacturing, (5) advanced rail equipment, (6) energy-saving and new energy vehicles, (7) electrical equipment, (8) agricultural machinery and equipment, (9) new materials, and (10) biopharmaceuticals and high-performance medical devices. The plan also seeks to establish 40 manufacturing innovation centers by 2025." Congressional Research Service, "The Made in China 2025 Initiative: Economic Implications for the United States," https://fas.org/sgp/crs/row/IF10964.pd; U.S. EXIM Bank, *Report to the U.S. Congress on Global Export Credit Competition.*

350. U.S. EXIM Bank, "Railroad Exports," accessed March 22, 2021, https://www.exim.gov/what-we-do/loan-guarantee/transportation/railroad-exports; U.S. EXIM Bank, "EXIM Loan Guarantee Helps Buyer Secure Competitive Financing for Railway Modernization Project in sub-Saharan Africa," accessed March 22, 2021, https://www.exim.gov/about/success-stories/exim-loan-guarantee-helps-buyer-secure-competitive-financing-for-railway; U.S. EXIM Bank, "Atlanta Business Exports Locomotives to sub-Saharan Africa with Financing from EXIM Bank," accessed March 22, 2021, https://www.exim.gov/about/success-stories/atlanta-business-exports-locomotives-sub-saharan-africa-financing-exim-bank; "US Exim funds Indonesia rail," *Global Trade Review*, October 22, 2014, https://www.gtreview.com/news/asia/us-exim-funds-indonesia-rail/.
351. U.S. EXIM Bank, *Report to the U.S. Congress on Global Export Credit Competition.*
352. U.S. EXIM Bank, "EXIM Launches 'Strengthening American Competitiveness' Initiative," press release, May 6, 2020, https://www.exim.gov/news/exim-launches-%E2%80%9Cstrengthening-american-competitiveness%E2%80%9D-initiative.
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354. Ibid.
355. For example, JBIC's (Japan) mandate doesn't even mention exports, but does specifically mention, among other things, securing natural resources that are important for Japan. In 2019, the Australian government expanded Efic's mandate to include a new overseas infrastructure financing capability. Moreover, Efic is mandated to also assess transactions based on a more general "Australian benefit" concept, and no longer just on the basis of whether a transaction increases the number of people employed in Australia during the term of an Efic loan. U.S. EXIM Bank, *Report to the U.S. Congress on Global Export Credit Competition.*
356. A "standard" is a document, established by consensus, that provides rules, guidelines, or characteristics for activities or their results. In general, standardization plays an important role in improving the rail sector's competitiveness by eliminating technical barriers to trade, decreasing costs, increasing efficiency and interoperability, as well as by facilitating market access for all stakeholders.
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358. CRRC annual reports, as translated and reported in: Bruyere and Picarsic, *Beijing's Dash for Global Rolling Stock Dominance*.
359. *CRRC 2019 Annual report* (CRRC Corporation Limited, 2019), https://www.crrcgc.cc/Portals/73/Uploads/Files/2020/4-27/637235827333140166.pdf.
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361. European Commission, "Mergers: Commission clears Alstom's acquisition of Bombardier, subject to conditions," press release, July 31, 2020, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1437.
362. In making the decision, Margrethe Vestager, former EU competition commissioner, stated that part of her thinking was that Chinese competitors were unlikely to sell trains in Europe anytime soon. European Commission, DG Competition, "Case M.8677 - SIEMENS/ALSTOM MERGER

PROCEDUREREGULATION 139/2004;" Rochelle Toplensky, Patrick McGee, and David Keohane, "The blunders that derailed European train merger," *Financial Times*, February 7, 2019, https://www.ft.com/content/c8a0e064-2a23-11e9-a5ab-ff8ef2b976c7.

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365. Pamela Barbaglia, Allison Lampert, and Gwénaëlle Barzic, "Bombardier has approached Alstom, Hitachi to forge rail merger, sources day," *Reuters*, January 24, 2020, https://ottawacitizen.com/transportation/rail/bombardier-scrambles-to-craft-rail-merger-with-alstom-hitachi-sources-2/wcm/a1620331-9a76-4d60-9391-903745b3dab2.

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368. The private sector is responsible for funding and directing all rail-related R&D.

369. As to the latter, the European Rail Traffic Management System (ERTMS) represents a regionwide innovation. As to the former, countries need to ensure their rail sector is coordinated so that R&D funding is used as efficiently as possible. Europe has done this through both the European Rail Research Advisory Council and the Shift2Rail initiative, which is the principal mechanism for European rail research and innovation. It is an institutional arrangement whereby rail firms and the EU contribute research funds that are managed jointly. Research grants are open to both members and non-members of Shift2Rail. This collective approach has allowed for more effective R&D as compared with the costs and risks of each firm pursuing its own R&D program. For example, in January 2020, the Shift2Rail Joint Undertaking issued a call for research proposals worth €146 million, of which 8 were for members and 11 were open to anyone. Of this, about €75 million is from the EU's Horizon 2020 fund. The EU should build on the collaborative research-model set up within Shift2Rail Joint Undertaking and ensure that a rail research program is included within the Horizon Europe Framework Programme 2021–2027. "Shift2Rail invites 2020 research proposals," *Railway Gazette*, January 8, 2020, https://www.railwaygazette.com/research-training-and-skills/shift2rail-invites-2020-research-proposals/55500.article.

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