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How China's Mercantilist Policies Have Undermined Global Innovation in the Telecom Equipment Industry

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China's state-backing of Huawei and ZTE allowed these companies to seize global market share from more innovative international competitors, reducing their growth in sales and investments in R&D. This, in turn, hurt global innovation in the industry.

KEY TAKEAWAYS

- Without unfair, mercantilist Chinese government policies and programs for its telecom giants, China would lack a globally competitive telecom equipment industry. Neither Huawei, nor ZTE, would have more than minor market shares, even in China.
- Chinese market-share gains have come at the expense of innovative telecom equipment providers in other countries. By artificially taking market share from more innovative companies, the latter have had less revenue to invest in cutting-edge R&D.
- As a share of sales, leading non-Chinese equipment companies invest more in R&D, and patent and contribute more to international standards when compared to Huawei and ZTE.
- Beijing's policies dramatically limit foreign access to China's huge telecom markets, providing them with a guaranteed source of revenue to attack foreign competitors.
- We estimate that if Ericsson and Nokia took all of Huawei and ZTE sales, there would be 20 percent more global telecom equipment R&D and 75 percent more essential 5G patents.
- Democratic market-based nations should no longer purchase equipment from Huawei and ZTE and should encourage other nations to not buy Chinese telecom gear.
- This will send a clear message to China that, going forward, systemic innovation mercantilism that hinders global technological innovation will no longer be tolerated.

INTRODUCTION

The telecommunications equipment industry serves wireless and wireline providers, including for voice, data, and video. The industry is technologically sophisticated, yet nowhere near mature. In the wireline industry, both switches and cabling regularly improve in speed and capacity. Each new generation of wireless technology—now moving into its fifth, known as 5G—brings order-of-magnitude improvements in wireless networks.[1]

This report examines how China's telecom equipment policies affect innovation in the industry globally. There is no question that, without unfair "innovation mercantilist" policies and programs, China would lack a globally competitive telecom equipment industry. Neither Huawei nor ZTE, China's two national champions, would have more than de minimis market shares, even in China. Nor is there any question that Chinese market-share gains have come at the expense of innovative telecom equipment providers based in other nations. In the 2000s, Chinese innovation mercantilism contributed to the demise of Canada's Nortel and America's Lucent, the world's two most innovative telecom equipment producers in the late 1990s. And since then, China's rise has come at the expense of global market share and profits for Europe's Ericsson and Nokia, the number two and number three players in the industry, respectively.

The question of impact on innovation is more complicated. As this report shows, China's state backing for Huawei and ZTE allowed the two of them to seize global market share from far more innovative non-Chinese telecom equipment companies by severely limiting their competitors' access to China and related markets, and supporting Huawei's and ZTE's rapid expansion overseas. This has eroded non-Chinese companies' revenue growth, which has slowed the rate at which they could increase spending on research and development (R&D), thus slowing their pace of innovation from what it otherwise would have been. Both Chinese companies, but particularly Huawei, invest significantly in R&D and generate a significant number of international patents. However, they patent less than their global market shares would predict, and considering patent quality and other measures of innovation, such as accepted 5G standards, Ericsson and Nokia still remain significantly ahead of Huawei and ZTE, even after unfairly losing global market share.

While it is impossible to definitively know the counterfactual—would there be even more innovation today if Huawei did not exist?—on net, the evidence suggests that would be the case, because more innovative firms would have more revenue to support more productive R&D.

So, while Chinese innovation mercantilism appears to have either killed, contracted, or slowed the growth of innovative foreign telecom equipment companies, it has allowed Huawei and ZTE to emerge and grow, which has helped them innovate, though not at the same rate as leading non-Chinese counterparts do per dollar of sales. And while it is impossible to definitively know the counterfactual—would there be even more innovation in the industry today if Huawei and ZTE did not exist?—on net, the evidence suggests that would be the case, because more innovative non-Chinese firms would have more revenue to support more productive R&D. ITIF estimates that if Ericsson and Nokia took all of Huawei and ZTE telecom equipment sales, global telecom equipment R&D would increase 20 percent, 5G standards contributions would increase 18 percent, and essential 5G patents would increase by 75 percent. In short, Chinese policies, and Chinese telecom equipment firms, on net, are a drag on global innovation.

It is time for policymakers in market-based economies to respond accordingly. There are three possible options to deal with the offenders: 1) the business version of a death penalty, 2) exoneration, or 3) the equivalent of imprisonment. The Trump administration, with its ban on sales of key technology exports to Huawei is attempting to impose the death penalty by starving the firm of needed inputs. But this unlikely to work, as Huawei appears to get the key technologies it needs for 5G systems elsewhere or produce them on its own. All the ban does it harm U.S. technology exporters.

Exoneration, which has been the path much of Europe has chosen, cannot be the answer, because it sends a clear signal to China that decades of unfair, innovation-mercantilist actions will be ignored, which only emboldens China to double down on these policies for other advanced technology industries like aerospace, life sciences, and artificial intelligence. Europe is only buying time before the inevitable; when Chinese firms dominate European advanced technology markets.

Rather "imprisonment" should be the answer. In other words, democratic, market-based nations need to work together to support global innovation by no longer purchasing equipment from Huawei and ZTE going forward, actively deploying advanced, allied-nation-produced broadband equipment domestically, and encouraging other nations around the world to buy non-Chinese telecom gear, too. This will send a clear message to China that, going forward, systemic innovation mercantilism that hinders technological innovation globally will no longer be tolerated.

A FRAMEWORK FOR UNDERSTANDING THE IMPACT OF TRADE ON INNOVATION

There are good reasons to believe that just as distorting domestic economic policies reduce domestic economic welfare, so too do foreign economic and trade policies—and not just in the practicing nation, but in other nations, and indeed in the entire global economy. One way to understand why is to examine the theory of the relationship between competition and innovation, because foreign entry and growth represents an increase in competition.

There has been a long tradition of scholarship to understand the relationship between competition and innovation. Stylistically this been portrayed as a debate between two leading economists: Kenneth Arrow and Joseph Schumpeter. Innovation economist Joseph Schumpeter has argued that firms with temporary market power from innovation (e.g., a patented product) would have both the resources and the incentive to innovate further. In contrast, firms with little market power and "normal" (e.g., low) rates of profits would not have the resources to effectively innovate.

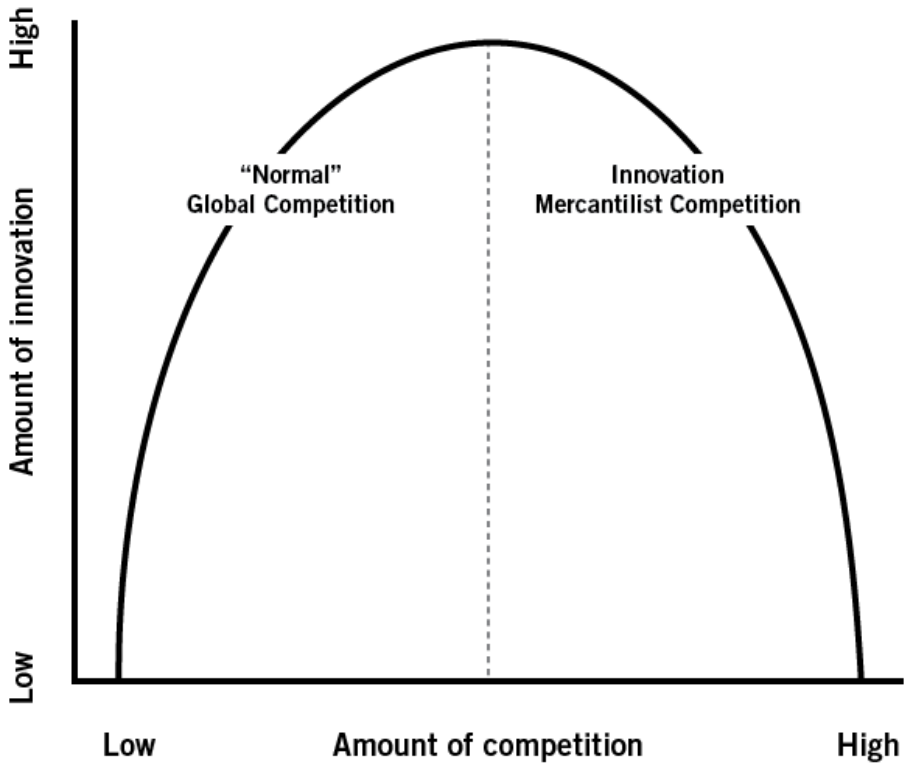
Schumpeter's argument has been challenged by Arrow, who has asserted that innovation would be greater in more competitive markets.[2] And economist Myeongwan Kim reprised Arrow's argument that increased competition, including from trade, "fosters innovation as it reduces the relative profitability of low-tech products. Firms cannot get rid of their 'trapped' inputs easily, having more incentives to allocate them to inventing new products or technologies."[3]

There is considerable reason to believe that, on balance, Schumpeter is correct. As the Obama Council of Economic Advisers reported, "Allowing firms to exercise the market power they have acquired legitimately can maintain incentives for research and development, new product introduction, productivity gains, and entry into new markets, all of which promote long term economic growth."[4] Likewise, noted economist William Baumol emphasized the extent to which even oligopolistic markets could produce innovation if firms are competing on innovation, not prices. He compared this oligopolistic competition to an arms race "that participants cannot easily quit."[5] Baumol went on to note:

> Oligopolistic competition among large, high-tech, business firms, with innovation as a prime competitive weapon, ensures continued innovative activities, and very plausibly, their growth. In this market form, in which a few giant firms dominate a particular market, innovation has replaced price as the name of the game in a number of important industries. The computer industry is only the most obvious example, whose new and improved models appear constantly, each manufacturer battling to stay ahead of its rivals.[6]

However, one way to square this circle between Schumpeter and Arrow comes from some scholars who argue that the relationship between competition and innovation resembles an inverted "U."[7] (See figure 1.) When a market is dominated by one or two firms, the firms might have the revenues to invest in innovation but lack the competitive pressures to do so, and innovation is hindered. In contrast, in fragmented and hypercompetitive markets, particularly ones made up of many small firms, firms tend to produce less innovation because, while they have the competitive motivation, they lack the revenues from superior profits to invest in costly R&D.[8] Numerous studies have confirmed this theory.[9] Firms need to be able to obtain Schumpeterian profits to reinvest back into innovation that is both expensive and uncertain.

Figure 1: The relationship between competition and innovation



So how exactly could competition from trade reduce innovation? There are two main ways. The first is if it reduces the size of the market for the innovative firms. Large markets enable firms to sell more. But if larger markets come with an even larger numbers of competitors, total sales per firm can fall or not grow as much as otherwise would be the case. We see this with respect to Ericsson and Nokia. This matters because innovation industries usually have high fixed costs of

design and development but relatively low marginal costs of production. In other words, the cost of the first product is extremely high, while subsequent ones are much less costly. In these industries, larger markets better enable firms to amortize those fixed costs over more sales, so unit costs can be lower and revenues for reinvestment in innovation higher. This is why firms in most innovation industries are global. If they can sell in 20 countries rather than 5, expanding their sales by a factor of 4, their costs increase by much less than a factor of 4. Numerous studies have found a positive effect of the ratio of cash flow to capital stock on the ratio of R&D investment to capital stock.[10] The more sales, the more revenue that can be plowed back into generating more innovations.

But if increased trade unfairly limits a firm's market, either by artificially introducing more competitors or by having one-sided trade that does not open a foreign market, sales for domestic innovators could shrink or stagnate. Trade barriers and distortions can limit scale economies if they limit market access to foreign firms in favor of domestic firms, and raise total global innovation costs by enabling more firms than necessary. Many of these barriers stem from policies that favor domestic innovation firms over foreign ones. China's "indigenous innovation policies" designed to favor Chinese-owned innovation firms are a case in point.[11]

The second related way competition can reduce innovation is by reducing the revenues and profits needed to reinvest in the next round of innovation. As Carl Shapiro noted, "[I]nnovation incentives are low if ex-post competition is so intense that even successful innovators cannot earn profits sufficient to allow a reasonable risk-adjusted rate of return on their R&D cost."[12] True innovation is not about risk in the sense that an "x" percent chance a given investment will yield a certain return can be modeled. Innovation is about uncertainty that cannot be modeled. And because innovation is about uncertainty, failure is often rampant. For every Apple succeeding with an iPhone, there are multiple companies that fail. Moreover, innovation industries face not just loss of market share from competition, but loss of existence. This reality evokes Joseph Schumpeter's dictum that "every piece of business strategy must be understood against the perennial gale of creative destruction."[13] This is why, for innovation industries, so-called Schumpeterian profits are so critical. They are profits that arise when firms are able to appropriate the returns from innovative activity. For if firms are assured at best of only normal returns from successful innovation, no innovator would take the enormous risk of investing in innovation. Innovation mercantilist-based policies can reduce profits in innovative companies by leading to market overcapacity and lower prices for competitive products more than what market forces would produce.[14]

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One form of overly strong competition relates to intellectual property (IP). The purpose of IP protection (e.g., patents) is to enable firms investing in innovation to make enough returns over a fixed period of time to recoup their costs, and more. As such, weak IP protection, state sanctioned IP theft, and other forms of non-market-based technology transfer weaken innovation.[15]

To be sure, this does not mean market-generated competition, from domestic or foreign sources, is detrimental. As William Lewis, the former head of the McKinsey Global Institute, has argued, there is perhaps no factor more important to driving economic growth than the presence of

competitive markets.[16] But this does not mean more competition is always better. Normally, markets will not produce an excess number of competitors in innovation industries. China, however, has done this through discriminatory government procurement and other policies favoring weaker domestic innovation firms.

In other words, to assess the impact of foreign firms and economies on innovation, one needs to determine where on the inverted U the competition exerts itself. It is likely that "normal" global competition supported by market-consistent government innovation policies exerts itself on the left side of the inverted U and improves innovation, both by spurring more competitive responses from incumbents and generating an innovation-based division of labor with developed nations specializing more in such activities. In contrast, innovation mercantilist competition likely exerts itself on the right side of the inverted U and harms innovation. This framing then provides a key insight into understanding the impact of Chinese policies on innovation, including in the telecom equipment industry.

TELECOM EQUIPMENT INDUSTRY BACKGROUND

In the 1970s, the two largest and most innovative telecom equipment companies were American: Western Electric and ITT. By the late 1990s, the two largest and most innovative were North American: Nortel, which was headquartered in Canada but employed tens of thousands of workers in the United States, and Lucent. (ITT, which was a U.S. company but had mostly foreign operations, was sold to the French company that became Alcatel.) In 1999, Lucent was almost three-times larger than its next two-largest rivals. Nortel accounted for over one-third of the capitalization of the Toronto Stock Exchange. By 2008, Nortel was bankrupt, and Lucent was a sliver of its former self, having been sold to Alcatel, which was bought by Nokia, a Finish company. Today, Chinese firm Huawei is the leading telecom equipment firm, with Chinese state-owned firm ZTE also a leader.

What did Huawei do to become the largest telecommunications equipment firm, and how did it and ZTE's rise affect non-Chinese companies, particularly in Europe and North America? In examining the rise of Huawei and ZTE, the answer is clear: Without innovation mercantilist policies, Huawei and ZTE would not exist, or at best would be minor niche players, even in the China market. Indeed, as Huawei's founder Ren Zhengfei himself admitted in 2002, without Beijing's policy of protecting Chinese companies from aggressive foreign competition at home, "Huawei would no longer exist."[17] And if Huawei did not exist, Nortel and possibly Lucent would certainly still be in existence today, and Ericsson and Nokia would have greater market shares.

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With Western Electric, part of AT&T, the United States had the most innovative telecom equipment company in the world for the entire 20th century. For example, in 1947, AT&T's Bell Labs had invented the transistor, arguably the most important technological breakthrough of the 20th century.[18] From its founding in 1925 to its divesture in 1995, Bell Labs averaged one patent per day, and by 1995 was averaging three patents per day.[19] *Fortune* magazine called it "the world's greatest industrial laboratory."[20] It was responsible for some of the most important inventions of the 20th century, including cellular technology, digital switches, fiber optics, lasers, the transistor, solar cells, satellite communication, undersea cables, and the UNIX operating system.[21]

In the 1990s, as digital communications technologies become more complex and required greater R&D investments, firms needed greater economies of scale to survive—which the rise of Huawei and ZTE reduced. At the same time, the 1996 Telecommunications Act unleashed an artificial and unsustainable investment frenzy that weakened Lucent and Nortel, which expanded too fast and financed too many unsustainable new market entrants. As a 2004 *Wall Street Journal* article noted, "The Chinese incursion comes at a time when the incumbents are still smarting from the recent, three-year bust that has claimed hundreds of thousands of jobs in the West."[22] This is reflected in the fact that after the accession of China to the World Trade Organization (WTO), Chinese exports of telecom equipment to the United States increased from $19 billion in 2000 to $124 billion in 2006, while U.S. exports increased much less, from $71 billion in 2000 to $129 billion in 2008.[23] This meant less needed revenue growth for North American firms. Today, Huawei and ZTE's 38 percent of global telecom equipment market leaves that much less for the Allied country producers.[24]

It would be one thing if China's telecom equipment dominance were the result of market forces: America could chalk up its losses to bad management or lack of competitive advantage. But market forces are not the driving factor: Government forces have changed the shape of the industry. Indeed, without China's often unfair and predatory industrial policies, China today would have no viable telecom equipment industry. As Peter Nolan wrote in 2001, "Compared to the global giants in the field, such as Lucent, [Huawei] stood little chance of winning in direct competition, without considerable state support."[25] Another study states: "The mythology surrounding these companies attributes their relative success to their 'success in market-place competition' not to government support. The blunt reality is that, in most cases, relative success required both high entrepreneurial achievements as well as state support."[26] In short, non-Chinese companies are not competing just with Chinese companies; they are competing with "China Inc.," a powerful system wherein the full weight of the Chinese state is brought to bear to support Chinese champions. And this is particularly helpful in the telecom equipment industry—as so many purchases are either from state-owned telecommunication providers or private companies that are deeply affected by national regulation—giving China extra leverage to influence not only private companies, but states as well.

As shown in table 1, China has deployed an array of policies to gain global market dominance in the industry, with most of them—such as forced technology transfer and domestically allocated markets—harmful to global innovation.

Table 1: Assessing China's telecom equipment industries policies on global innovation

Type of Policy	Impact on Global Innovation
Funding technology development and sharing with industry	Harmful
Forced technology transfer	Harmful
Intellectual Property theft	Harmful
Currency manipulation	Harmful
Export financing above OECD guideline levels	Harmful
Tariffs	Harmful
Government-allocated domestic market shares to Chinese firms	Harmful
Political hardball to gain foreign markets	Harmful
Supporting foreign corrupt business practices	Harmful
R&D tax incentives, favorable to Chinese firms	Neutral
R&D subsidies (favorable to Chinese firms)	Neutral
Low cost financing for Chinese firms only	Neutral
Limited export control regime	Neutral
Supporting STEM education	Helpful
Supporting more rapid broadband rollout, including 5G cell sites	Helpful

CHINA TARGETS THE INDUSTRY WITH FORCED FOREIGN JOINT VENTURES

In 1979, the Chinese government designated the telecom equipment industry as a strategic one for which China had sought "absolute control."[27] But it took China three decades to get that control. By the early 1980s, China's Post and Telecom Industrial Corporation controlled 28 equipment factories. But these firms' technological backwardness was holding back China's progress in telecommunications. As a result, the Chinese Communist Party (CCP) allowed domestic telephone companies to buy more technologically advanced foreign equipment. But it quickly evolved to requiring foreign companies that wanted to sell in China to not only set up production there, but to do so in joint ventures (JVs) with Chinese firms. As a result, China went from 100 percent of the market provided by imports in 1982 to 0 percent in 2000, with 60 percent from foreign JVs and 40 percent from indigenous suppliers.[28] In other words, China had no desire to engage in foreign trade in this sector; it sought and obtained autarky.

Why did foreign firms agree to sell the Chinese, in the words of Lenin, "the rope to hang themselves by"? The answer is Chinese monopsony: The government controls the market. In the late 1970s, China's Ministry of Posts and Telecommunications approached virtually all foreign telecom equipment companies to explore opportunities for tech transfer through JVs. All refused, not wanting to give China their valuable technology. But one broke ranks: Belgium's Bell Telephone Manufacturing (BTM) company, a subsidiary of American telecommunications equipment giant ITT. Bell agreed and transferred the System 12 technology, at the time the most advanced in the world, to China.[29] The Belgian government even provided long-term financing to the Chinese business partner and agreed to transfer technology for component and chip production. As one Chinese analyst wrote, "That was remarkable. At the time no other supplier was prepared or able to offer the transfer of such advanced technology."[30] One sticking point was

that such technology transfer—as opposed to a sale of the telecom switches themselves—was restricted under Coordinating Committee for Multilateral Export Controls (COCOM) rules. But the Belgian government and ITT aggressively lobbied the U.S. government and other members for an exemption. BTM not only transferred key technology to their partner, Shanghai Bell, it also extensively trained managers and engineers.

The Chinese government then dictated that domestic telecom companies should buy their equipment, provided generous subsidies to buyers, and reduced Shanghai Bell's taxes and tariffs for imported components. This sent a clear signal to foreign companies that if they wanted to sell in China they had better get in line and form JVs. In addition, to encourage more JVs, the government set quotas on the import of telecommunications equipment for each firm. As one study wrote, "[T]he size of the quota was linked to a company's performance in localizing production and transfer technology to Chinese companies."[31]

Once the dam was broken, foreign companies had no choice but to comply and form JVs if they wanted any part of the fast-growing Chinese market. So, in 1988, Siemens formed a JV with a factory owned by the Ministry of Electronics Industry to establish the Beijing International Switching System Corporation. In 1993 and 1994, Siemens set up 14 JVs.[32] Ericsson, Fujitsu, Lucent, Motorola, NEC, and Nortel also all formed JVs.[33] By 1998, Lucent had six JVs. In the early 2000s, a number of JVs intended to transfer wireless technology were established: Alcatel and Datang, Ericsson and ZTE, and NEC and Torch.

Huawei directly benefited from JVs. Motorola and Huawei set up joint laboratories for communication systems research in 1997. In 2000, Huawei and Lucent established a joint lab to focus on microelectronics and optoelectronics. That same year, NEC and Huawei established a "3G Internet Open Lab" in Shanghai. As Peilei Fan noted, "The objectives of establishing the Open Lab are to create an open platform to support the 3G mobile developments in China and to provide end-to-end total mobile solutions for mobile operators."[34] Huawei and Siemens entered into a JV for wireless. The JVs were extensive. As one study noted:

> In order to be successful in the [Chinese] market it would be essential for Western manufacturers to work out joint venture agreements with indigenous Chinese companies, manufacture locally, and work out extensive technology transfer agreements. As a result, numerous manufacturing joint ventures with Chinese companies were forged and business moved ahead quite nicely, with the communist nation buying equipment from every western vendor imaginable.[35]

These coerced—or at least pressured—JVs provided extensive help to Chinese firms. As one case study of what was presumably Nokia (the name was changed to NHT to ensure anonymity) found:

> A major technology transfer project was started in mid-1998 to bring in the latest technology and this has resulted in all mobile switching equipment for the Chinese market being supplied by NHT in association with its subcontractors in China and the local partner … A large number of employees went to Europe for between one and three months in 1998 as part of the major technology transfer project…. The second phase of technology transfer was to further develop the company's subcontractors…. Local companies such as Huawei have this type of assistance."[36]

In addition to JVs, Alcatel, Ericsson, Motorola, NEC, Nortel Siemens, and Sony Ericsson also established freestanding R&D centers in China that trained thousands of engineers and led to know-how and technology being siphoned off to domestic Chinese companies.[37]

But even forced JVs and Western corporate R&D labs in China not directly involving Huawei played an important role in helping the company. This is because the Chinese government made sure JVs benefited not just from the direct Chinese partner, but other Chinese firms, including Huawei. For example, Chinese industrial ministries organized engineers from other parts of the domestic industry to get training or job rotations at the JV firms. Shanghai Bell JV engineers trained other engineers from across the nation because the Ministry of Posts and Telecommunications made their continued support dependent on it.[38] As one study notes:

> The presence of many JVs in China fostered the diffusion of technology know-how across the country … there was a broad-ranging knowledge transfer and exchange involving R&D, production, subcontracting, marketing, after-sales services, and local human resource training. Shanghai Bell and other joint venture establishments fostered the diffusion of technological know-how across the country.[39]

For example, Shanghai Bell cooperated with local universities and research institutes.[40] The Chinese general manager of the JV facility stated that the Shanghai Bell JV had been a "big school," fostering a great number of qualified engineers in China.[41] In addition, the Chinese government, in part through the Ministry of Post and Telecommunications and the state-owned Luoyang Telephone Equipment Factory formed a consortium to work with Shanghai Bell to develop indigenous digital switches, which were subsequently copied by Huawei.[42]

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As Xiaobai Shen wrote: "Technological learning has not been solely confined to Shanghai Bell. Rather it has been widely spread through both informal and formal channels to System-12 users, component producers and other related agents.[43] Similarly, as another study noted: "[C]ritical know-how from Nokia has been transferred to Chinese multinationals [including Huawei] via these employee transfers." Another study found that telecom equipment JVs had very high rates of technology spillovers to Chinese firms not part of the JV.[44]

Why did the companies do this? Were they naïve? Some may have been, but as a Rand study found:

> Foreign market entrants are fully aware that these technology co-development relationships with Chinese companies are aiding domestic partners at their expense, but they feel that they have no other choice, given the structural asymmetries in the market … Motorola's chief of network solutions in China even told a Western reporter that he has no doubt that Huawei plans to use its partnership on GSM technology to replace Motorola's base stations with its own one day.[45]

Likewise, when asked why Nortel established a massive R&D facility in China, the CEO stated that unless he promised the Chinese government that Nortel would open an advanced technology lab there, Nortel would not be able to sell to the Chinese telecommunications providers.

CHINA'S SHIFT TO INDIGENOUS INNOVATION

JVs were always a means for China to fulfill its long-standing goal of building its own domestic industry with Chinese-owned firms free from any ties to Western business. When Ren Zhengfei, Huawei's founder and CEO, met with CCP general secretary Jiang Zemin in 1994, he told him that a country without a domestic telecoms-switch industry was like a country without a military. By 1996, under Ren's prodding, the Chinese government had shifted its industrial policy to supporting its own telecommunications equipment companies, rather than JVs.

Government Equipment Development Programs

A key component of the switch to indigenous innovation was direct funding of Chinese firms. In the early 1980s, CCP called on the People's Liberation Army (PLA) to make more contributions to the economy. As a result, PLA funded a variety of commercial technology development projects, including telecom switches, at a time when Ren Zhengfei was a member of PLA. China funded more than 100 government research institutions with over 600,000 technicians and specialists engaged in various types of R&D related to the production of telecommunications equipment and other high-technology goods.[46]

Both Huawei and ZTE got an enormous leg up by having the government not just support early stage basic and applied research, but to actually build and donate a prototype of their first major digital product.

Along with other government agencies, including the Ministry of Posts and Telecommunications, the government paid for the development of the HJD-04 digital switch, the first digital switch made by a Chinese organization. As Emiroğlu wrote, "Under the leadership of MPT, technological know-how diffusion of HJD-04 was transferred through the national telecom equipment industry. HJD-04 development team provided consultancy services to domestic telecom equipment firms, specifically to Huawei and ZTE."[47] In fact, he noted that the HJD-04 directly led to the development by Huawei of their C&C08 switch, their first entry into the market, and by ZTE of their first digital switch. In other words, both Huawei and ZTE got an enormous leg up by having the government not just support early stage basic and applied research, but to actually build and donate a prototype of their first major digital product.

Huawei also greatly benefited from the movement of engineers trained at these government facilities. As Qing Mu and Keun Lee wrote:

> After the development of the HJD-04 in 1991, knowledge diffusion was further amplified through the inter-flowing of engineers or related persons, which finally led to successive development of other four types of digital automatic switches (C&C08, EIM-601, ZXJ-10 and SP-30) by other indigenous firms. The later development of other types of digital switches by firms such as ZTE, Datang, and finally Huawei, all benefited from knowledge diffusion via inter-firm mobility of skilled engineers. For example, Huawei's location at Shenzhen and its higher salary levels attracted skilled manpower from the Great Dragon (original manufacturer of HJD-04). Consequently, many skilled young engineers who had mastered or at least had some knowledge of the HJD-04 system left the Great Dragon for Huawei (or ZTE). They contributed to the R&D of another digital switching system, C&C08, in Huawei.[48]

In addition, Huawei and ZTE have benefited from direct government funding. ZTE has been involved in 19 R&D projects of the "863 Plan," and in 1996, was chosen by the Ministry of Science and Technology as one of the high-tech enterprises to spearhead the "Torch program." In 1998, the State Economic and Trade Commission designated ZTE as one of the national "Centers of Technology Development."

The government also gave domestic producers legislated priority status and provided them with low-interest loans. Huawei and Datang (another leading Chinese provider) became "national laboratories"—an institutional designation that leads to preferential funding that was previously reserved for research institutes and universities.[49]

Protected Domestic Markets

Once China had developed domestic capabilities, it set up import barriers. It stopped arranging loans to import equipment, and put on steep tariffs on imports: 15.6 percent in 2001.[50] Moreover, China consolidated its telecommunications service providers into three giant companies in order to foster "indigenous innovation," that "encourages relevant departments, enterprises, and institutions to give priority to indigenously innovated products," and "state-owned assets management departments shall use indigenous innovation as a key criterion in assessing telecom operators."[51] In other words, Chinese telecom providers would be evaluated and rewarded, or punished, by the government for how much they bought from Chinese companies.

The government continues to do the same in wireless communications, wherein Huawei and ZTE are each guaranteed over one-third of the market for 5G contracts. For example, of China Mobile's recent $5.2 billion award for build-out of 232,143 5G base stations, Huawei got 57.2 percent of the contract by number of base stations, with ZTE getting 28.7 percent and Ericsson 11.5 percent.[52] Notwithstanding the quality and price competitiveness of the Ericsson offering, the only reason a non-Chinese firm is allowed to gain 5G market share is to continue the illusion of an open competitive market, and to give the Chinese government leverage over European governments that seek to limit Huawei deployment in Europe. If the EU threatens to take strong action against unfair Chinese practices, the Chinese government can retaliate by threatening to completely exclude European providers.[53]

Given China is the largest telecommunications market in the world—with approximately half of the global 5G base stations now in China—this market guarantee is the biggest "subsidy" provided to Huawei and ZTE, giving them billions of additional RMB annually in revenue, of which they invest about 15 percent into R&D. China Mobile, China's biggest mobile operator, has 960 million subscribers, more than all the mobile subscribers in Europe and America combined.[54]

Indeed, over 85 percent of carrier spend in China is to Huawei and ZTE. Moreover, Chinese-government policies give Huawei and ZTE an advantage in other markets. In many developing nations, China ties its foreign aid to commitments to buy Chinese equipment. And in other nations, the Chinese government plays hardball to get countries to buy from Huawei—as when the Chinese ambassador to Denmark warned the Danish government that unless the country's telecom provider bought from Huawei, China would not sign a trade agreement with Denmark's semi-autonomous Faroe Islands.[55]

Huawei and ZTE have the same if not greater advantage in adjacent markets, such as core routers. Cisco, the leader in this space, has almost half the non-China market share, with Huawei under 20 percent. But because Cisco's China share is tiny (around 5 percent) and because the Chinese market is so large, Huawei has around 50 percent greater global market share than Cisco. These protected Chinese revenues let Huawei fund R&D and other activities, not just in core routers but also 5G equipment. We see the same dynamic in telecom equipment markets.

These "safe" and assured markets provide Huawei and ZTE with extra resources to compete with Ericsson, Nokia, and Samsung in other markets. This also provides them with a valuable leg up because they were "inoculated" at the end of the LTE (4G) investment cycle. Wireless investment in particular is cyclical, as carriers rush to install the latest generation of gear and investment then lagging until the next generation. The Chinese government ramped up 5G deployment—ensuring virtually all of it went to Chinese companies—so their revenue growth continued. This gives them an enormous advantage over non-Chinese companies wherever 5G deployment is more market-driven and economically efficient.

Given China is the largest telecommunications market in the world, this market guarantee is the biggest "subsidy" provided to Huawei and ZTE, giving them billions of additional RMB annually in revenue.

Undervalued Currency

Huawei and ZTE have long benefited from a deeply undervalued Chinese currency, which provided it with a 25 to 35 percent price subsidy.[56] The discounted currency, which raised the price of imports, was not all that important to gaining domestic market share because that market share was allocated by the government. But it was a critical factor in allowing Huawei and ZTE to penetrate foreign markets because it could significantly undersell its competitors, more than making up for the lower quality of its products. Again, it used that revenue from increased global market share to invest more in R&D to improve its products.

Lack of Restraints on Foreign Corrupt Practices

American and foreign firms that have substantial operations in the United States, such as Ericsson and Nokia, are subject to the U.S. Foreign Corrupt Practices Act, which limits their ability to bribe foreign government or business officials. While well-intended it has the unintended consequence of tilting the playing field against these firms because Huawei and ZTE are less constrained by this.[57] The Chinese government does not engage in significant prosecution of Chinese companies for such acts. As a result, those companies can and appear to engage in unethical practices, such as bribes, to win foreign contracts.[58] For example, the Norwegian Council on Ethics recommended excluding ZTE from its government pension fund investments.[59] And a report from RWR Advisory estimated that "51% of Huawei's transactions since 2012 (by value) have taken place in countries that score high on the corruption risk scale."[60] To the extent bribery and other dodgy business practices distort carrier decisions, this could reduce global innovation by decreasing market share of the more innovative companies.

Limited Export Control Regime Constraints

As companies with significant operations in the United States, Ericsson and Nokia must comply with U.S export control rules, which require companies to obtain approvals to sell to designated nations. China has no such regime. As a result, they have more flexibility to sell to nations that

require regulatory approval for non-Chinese companies. Even when these companies can get approval, the approvals often take months to obtain, giving companies an advantage in tendering bids. And while the Trump administration did bring action against ZTE and Huawei for violating U.S. export control law, these companies still have more leeway in exporting to restricted countries.

Tax Incentives and Low-cost Financing

Huawei also saved as much as $25 billion in taxes between 2008 and 2018 due to state incentives to promote the tech sector.[61] It also benefited from significant low-cost financing from Chinese-government banks. As Chen wrote:

> When Chinese Premier Zhu Rongji learned in 1996 that Huawei was short of funding for its global expansion plan Huawei, he immediately instructed the accompanying heads of the four major commercial banks: "In order for the Chinese program-controlled switchboard to compete on the global market, we must provide buyer's credit". He also instructed the bankers to provide direct financial support to Huawei. The buyer's credit immediately provided Huawei with direct access to bank funding for receivables from its sales. And the direct bank loans from all major banks in Shenzhen immediately relieved Huawei from past funding hurdles and helped pave its way for skyrocketing growth till this day.[62]

Huawei also saved as much as $25 billion in taxes between 2008 and 2018 due to state incentives to promote the tech sector. It also benefited from significant low-cost financing from Chinese-government banks.

Two years later, the China Construction Bank lent Huawei 3.9 billion RMB in buyer's credit, representing 45 percent of the total such credit it extended that year.[63] As the *Wall Street Journal* reported: "Huawei had access to as much as US$75 billion in state support over the past 25 years, including grants ($1.6 billion), credit facilities ($46.3 billion), tax breaks ($25 billion), and subsidized land purchases ($2 billion)."[64]

Generous Export Financing

Chinese telecom equipment companies have long been eligible for preferential interest rates on export credits from China's Export-Import bank and the China Development Bank.[65] As one study noted, these financing packages "may include but are not limited to interest free financing, loan periods up to 30 years, payment holidays for up to 2–4 years, and total financing as high as 130% of the equipment purchase to cover ancillary items such as installation, training, and future maintenance."[66] As the U.S. Ex-Im Bank concluded, "Most of the terms and conditions of their [China Exim Bank's] financing did not and do not fit within the OECD [(Organization for Economic Cooperation and Development)] guidelines."[67] Chinese banks have made loans to bail out foreign telecom service providers that are linked to buying equipment from Chinese companies. One study found that "since 2015 China has provided more funding each year to support its exports than the OECD's 36 member-nations combined."[68]As China rolled out its Belt and Road initiative to support Chinese exports to emerging markets and parts of Europe, Huawei benefited substantially. Indeed, in a 2016 speech, a senior Chinese official, Zhang Yansheng, noted: "If it wasn't for the Belt and Road Initiative, there wouldn't be Huawei."[69]

In May 2019, *The Washington Post* reported that, "state-owned Chinese banks have made a $100 billion line of credit available to Huawei customers."[70] As the article noted, "[Though] less than 10 percent has been used, even $10 billion dwarfs the $200 million in new loans the U.S. Export-Import Bank granted to all customers in 2017."[71] Access to cheap capital is one of the many reasons Huawei has been able to undercut competitors on price, including when it underbid Ericsson by 60 percent last year to provide equipment for Holland's next-generation 5G wireless network.[72] Some have also asserted that the China Development Bank will provide more generous terms to a foreign telco if the government places the contract with the Chinse firm without engaging in a public tender.

Chinese telecom equipment providers also benefited from the government strong-arming input suppliers to lower their prices. For example, in 2015, China's National Development and Reform Commission fined Qualcomm, the world's largest producer of smartphone chips, $975 million for purportedly using its dominant market share to overcharge Chinese telecommunications firms for its patent royalties (something the EU, Japan, and the U.S. governments concluded it was not doing). In addition, it forced Qualcomm to offer 3G and 4G licenses at a lower price in China than Qualcomm's normal wholesale rate. This not only provided Huawei with a substantial subsidy, it cut revenue from its competitor—as Huawei produces chips (through its HiSilicon group) that compete with Qualcomm. And as of this year, it outsells Qualcomm in China for chips in smartphones.[73]

IP Theft

Finally, the rise of Chinese equipment firms is not complete without understanding the role of IP theft. Many Chinese companies use IP theft as a way to accelerate their technological capabilities. Datang Telecom, a telecom equipment provider, stole technology from Lucent.[74] In 2008, Hanjuan Jin, a former Motorola employee, was stopped at Chicago's O'Hare airport with over 1,000 Motorola documents in her possession as she was traveling to China on a one-way ticket. That same year, Motorola sued five former workers for allegedly sharing trade secrets with Lemko Corp, which then allegedly passed them on to Huawei. Motorola claimed the workers sent emails tagged "Motorola Confidential Proprietary" to Huawei.[75] According to federal prosecutors, Lemko was building wireless technology for Huawei based on Motorola technology.[76]

The ability to steal IP would explain why Huawei's R&D spending was significantly less than Nokia's and Ericsson's, and persistently lower as a ratio to gross profit prior to 2012, but its patenting rate was higher.

There have been many other allegations of IP theft by Huawei, including using Cisco router source code. Cisco General Counsel Mark Chandler wrote, "[T]his litigation involved allegations by Cisco of direct, verbatim copying of our source code, to say nothing of our command line interface, our help screens, our copyrighted manuals and other elements of our products."[77] A U.S. Justice Department case against Huawei reads:

> To obtain the intellectual property of the Victim Companies, the IP Defendants sometimes entered into confidentiality agreements with the owners of the intellectual property and then violated the terms of the confidentiality agreements by misappropriating the intellectual property for the IP Defendants' own commercial use … On other occasions, the IP Defendants used proxies such as professors working at research institutions or third-party companies, purporting not to be working on behalf of the IP Defendants, to gain access to the Victim Companies' nonpublic intellectual

> property. Those proxies then impermissibly provided the Victim Companies' nonpublic proprietary information to the IP Defendants.[78]

It goes on to state, "HUAWEI used a proxy to obtain information about Company 6's proprietary technology. Specifically, a professor of a PRC research university (the "Professor"), an individual whose identity is known to the Grand Jury, gained access to Company 6's proprietary technology on Huawei's behalf."[79]

Perhaps the most egregious known case of IP theft involves the now-defunct Canadian company Nortel.[80] In 2010, Brian Shields, the head of cybersecurity for Nortel, found that Chinese hackers had been inside Nortel computer systems since at least 2000.[81] Moreover, when the Canadian Defense Department took over the Nortel building after it went bankrupt, they discovered listening bugs had been planted.[82] As one telecom industry veteran said, "[B]y 2004, it was clear to many that Huawei was copying Nortel's telecom hardware, and even its instruction manuals."[83] Shields stated, "Nobody would be interested in these kinds of documents other than a competitor … In my opinion, looking at what the hackers went after, it is likely these documents made it to Huawei."[84]

The ability to steal IP would explain why Huawei's R&D spending was significantly less than Nokia's and Ericsson's, and persistently lower as a ratio to gross profit prior to 2012, but its patenting rate was higher. As one scholar wrote: "[I]ncredibly, Huawei had over 3.7 times the number of patent families as Nokia's from 2003–2012, or 28,726 patent families compared to Nokia's 7,675, and three times as Ericsson's from 2011–2014, or 18,177 patent families compared to Ericsson's 6,107."[85] The author suggested that one explanation for this is that Huawei was able to obtain IP without having to conduct the R&D to develop it, as Nokia and Ericsson did.

COMPARATIVE INNOVATION PERFORMANCE

There should be no question that absent a slew of long-standing Chinese-government policies and practices, the lion's share of which were in violation of WTO rules, Huawei and ZTE would be much smaller companies today, if they would even exist. So, what then was the effect on telecom equipment innovation both outside of China and globally of artificially propping up these two competitors?

There can be no doubt that China's government-orchestrated rise of this industry slowed the growth of innovation outside of China. As noted, China's rise played some role in the weakening of Lucent, and a stronger role in the bankruptcy of Nortel. Both firms were weakened by strategic mistakes and the market downturn of the early 2000s, but Chinese competition reduced the headroom they might have had to recover and turn around. In addition, by taking market share away from other companies, including Nokia and Ericsson, Chinese firms reduced the amount of R&D they otherwise would have had.

But the key question is whether the additional innovation from Huawei and ZTE made up for the reduced growth of innovation outside China. If these two companies were equally or more innovative per dollar of revenue than non-Chinese companies, the global impact on innovation could very well have been positive. But in fact, data on R&D spending, standards contributions, and patents suggests this was not the case.

This section compares the four leading telecom equipment companies—Ericsson, Huawei, Nokia, and ZTE—on available indicators of innovation, including R&D, patenting, and standards contributions. A fifth player, Samsung, could have been included, but for the sake of simplicity

and because their wireless market share is still modest, although growing, they were not. However, indicators such as patents and standards contribution per sales suggest they are significantly more innovative than Huawei and ZTE, and even more innovative than Ericsson and Nokia.[86]

To be sure, these are not the only measures of innovation, nor in fact the best. But they have the virtue of being objective and quantitative, compared with measures of actually innovativeness of company product offerings that depend on expert opinion. Moreover, while we believe these measures are linear to some extent (i.e., more standards essential patents are positively correlated with more product innovation), the relationships are by no means perfectly linear.

One key challenge in comparing the companies is transparency of trustworthiness of Chinese-company data. Neither Huawei's nor ZTE's financial reporting is as transparent or potentially accurate as Western-company reporting, which must be vouched for by third-party auditors. In addition, Huawei is not publicly listed, while ZTE is a state-owned enterprise, meaning it has significantly less transparency than a private, publicly listed company. Also, compared with companies such as Ericsson and Nokia, Huawei does not break down sales by other nations or R&D by major product line. Likewise, there is no way to know whether Huawei is actually making money on its telecom equipment business or is subsidizing it from profits from its large handset business.

Corporate R&D

One indicator in innovation is business spending on R&D. To be sure, R&D is an input, not an output, measure. But it is a one indicator of innovativeness. All four companies invest a considerable share of revenues in R&D, as would be expected in such a technology-intensive industry. But in 2019, Nokia invested 40 percent more as a share of revenues than Huawei and ZTE, and Ericsson invested 20 percent more.[87] (See table 2.) Similar differentials are also seen when looking at the average of 2017 to 2019 (21 percent for Nokia, 17 percent for Ericsson, and 14 percent for Huawei).[88] The Nokia and Ericsson leads may in fact be higher, as there is certainly some speculation that Chinese companies inflate R&D expenditures in order to satisfy government expectations.[89]

Table 2: Telecommunications industry firm R&D investment for first half of 2019[90]

Company	R&D investment as % of total revenues
Nokia	21.2
Ericsson	18.0
Huawei	15.0
ZTE	14.9

So, what would be the impact on R&D if Huawei and ZTE did not exist? To estimate that, we calculate total network sales from each of the four companies from 2015 to 2018, and the percentage share each country has.[91] We then calculate the total revenues for Ericsson and Nokia, and then allocate all Huawei and ZTE revenues for these years on a pro rata basis to Ericsson and Nokia. Next, we calculate the R&D-to-sales ratio for each of the four firms. We then reduce the revenues of Huawei and ZTE to zero and allocate the increased revenues to Ericsson and Nokia, and multiply this new revenue by each company's R&D-to-sales ratio to estimate additional R&D. The result shows that without Huawei and ZTE, total R&D by Ericsson and Nokia increases (assuming the R&D-to-sales ratio stays constant with higher revenues) by $6.4 billion over the period, for an increase of 20 percent. (See figure 3.)

Patenting

When it comes to patenting, at first glance it appears Huawei is the leader. Some studies have shown Huawei has a significant lead in 5G patents.[92] But patent counts need to be adjusted for global market share, as one would assume global market share should be roughly correlated with patenting because companies with more revenue have more to invest in R&D (which is also partially positively correlated with patenting), which in turn leads to inventions that can be patented. We calculate whether a company receives a greater share of patents than its market share for the four companies.[93] We then divide total number of patents by the market share of the four firms globally.[94] This equals the patent intensity.[95] For example, Nokia's score of 7,013 is calculated by dividing its total number of 5G patents (1,683) by its global wireless market share of the four firms (24 percent). For 5G patents, Nokia scores 7,083; ZTE 4,013; Ericsson 3,679; and Huawei last with 3,294. (See figure 2.)

Without Huawei and ZTE, total R&D by Ericsson and Nokia increases by $6.4 billion over the period, for an increase of 20 percent.

However, there is considerable agreement in the scholarly patenting literature that raw patent counts are an insufficient measure of innovation because they do not control for how innovative the discovery is. Any accurate assessment of innovation using patents has to control for quality and impact before measuring patent intensity (patents as a share of market share). As one study by Matthew Nobel, Jane Mutimear, and Richard Vary, analysts at the law firm Bird & Bird, noted, "Any study that fails to apply essentiality weightings is simply guessing as to 5G leadership and cannot be relied on."[96] When measures to control for this are included, the picture is quite different, with Huawei and ZTE lagging Ericsson and Nokia.

A 2018 study of 5G patents showed that while Huawei has more patents, its average quality, along with ZTE's, is lower, with Samsung, Ericsson, and Nokia (in that order) being higher.[97] The study shows that when total strength of all patents, rather than the simple number of patents, in a company's portfolio is assessed, Huawei goes from second behind Qualcomm to eighth; and ZTE goes from fifth to ninth. When looking at patent quality and strength, Qualcomm Samsung, LG Electronics, Nokia, and Inter Digital all lead Huawei, with Ericsson close behind.

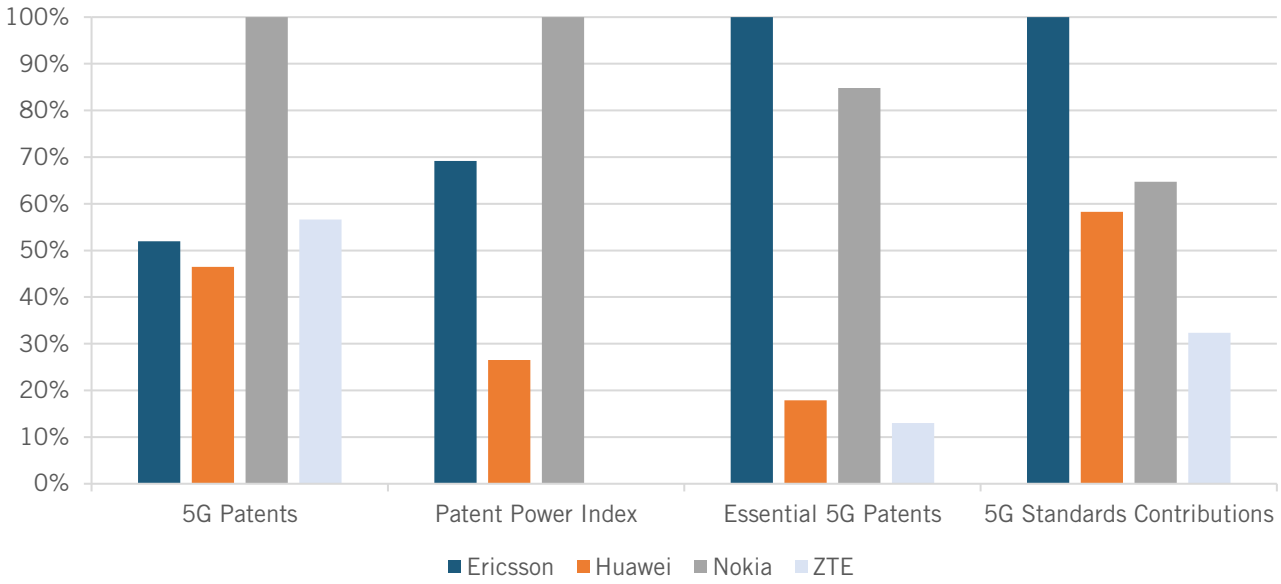
Moreover, it appears the rise of the Chinese firms is negatively correlated with changes in innovation for foreign competitors. The patent quality index peaked for Nokia in 2014, and Ericsson in 2016. In contrast, ZTE and Huawei were at their peaks in 2019 when this data was collected.

Another study by the IEEE Spectrum generated a Patent Power Scorecard that takes into account not only quantity but quality of patents, as reflected in characteristics such as growth, impact,

originality, and general applicability. Of the top 20 companies internationally in 2017 in the communication and Internet equipment industry, ZTE does not even make the list. Of the remaining three companies, Nokia leads with a score of 1,332; Ericsson 806; and Huawei 603. Using the same method to adjust for market share, Nokia and Ericsson lead by a significant margin, with intensity scores of 5,550 and 3,838 respectively, with Huawei at 1,471.[98] (See figure 2.)

Another study looked only at patents identified as essential to 5G innovation overall (standards-essential patents) and awarded in the United States and the EU. This is perhaps the best measure of innovativeness as it reflects new cutting-edge technology and inventions that are so important that they are patented in the two most important markets. Here the differences are even clearer, both absolutely and controlling for global market share. Adjusting for market share, Ericsson leads with a score of 78, Nokia follows with 66, and Huawei and ZTE score much lower, at 14 and 8 respectively.[99] Another way to adjust for market share is to use purchasing power parity (PPP)-based market shares that attempt to control for differences in price levels between countries.[100] In other words, because the cost of doing R&D is lower in China than in Sweden, for example, Chinese companies should be able to do more R&D per dollar of revenue and hence produce more innovations per dollar. Here the differences are even greater, with Ericsson at 166, Nokia at 119, ZTE at 15, and Huawei at just 8.

Figure 2: Company scores on selected innovation indicators as a share of the leading company score[101]



A study by Tokyo-based research company Patent Result assessed the quality of the patents filed in the United States by Huawei and two U.S. companies, Intel and Qualcomm. They used a set of criteria including originality, actual technological applications, and versatility. The study found that only 21 percent of Huawei patents could be classified as highly innovative, compared with 32 percent for Intel and 44 percent for Qualcomm.[102]

5G Standards Contributions

When looking at 5G standards-setting technical contributions that were approved by the 3GPP standards group, and controlling for market share, Ericsson leads with a score of 24,495; Nokia follows with 15,850; Huawei scores 14,280; and ZTE is at the bottom with 7,920.[103] (See figure

2.) When using PPP to calculate market shares, the standard-setting index scores are even more skewed in favor of Ericsson and Nokia, with them scoring 53,369 and 28,703 respectively, and Huawei and ZTE scoring 8,476 and 14,791 respectively.

Patent Purchases and Sales

Huawei has also relied heavily on purchasing patents from companies in other nations, including those that went out of business because of unfair Huawei competition. As one article describing the Patent Result study found: "Huawei has been on a patent-buying spree in an apparent bid to boost the overall quality of its huge portfolio of patents on crucial technology." [104] Huawei has purchased over 500 patents from foreign companies, including 250 from U.S. companies. "High quality" patents account for some 67 percent of these. Again, this is not a reflection of internal, organic innovation capabilities as much as it is a company with government-supported deep pockets being able to buy innovation from other players.[105]

Related to this is net patent revenue. All technology-based companies both license patents and pay for the rights to use other companies' patents. All else being equal, companies with net-positive balances are likely to be more innovative. It does not appear Huawei or ZTE list this figure, but in 2019, Ericsson netted 9.6 billion SEK, or approximately 4 percent of sales in 2019 in patent revenues.

Other Indicators

The study also found evidence that a not-insignificant share of Huawei's innovation relied on Western resources. Of Huawei's 30 best engineers measured by using its assessment of patents developed by the company, more than half (17) were recruited from foreign companies, mostly in the United States and Canada (presumably the latter from Nortel). According to an article that described the study, "People poached from U.S. companies like Motorola and other IT groups are now acting as the driving force behind Huawei's technological advance."[106] It seems reasonable to assume that if Huawei had not taken market share from Western companies, these highly talented engineers would still be employed by these companies.

Of Huawei's 30 best engineers measured by using its assessment of patents developed by the company, more than half (17) were recruited from foreign companies, mostly in the United States and Canada.

Another indicator is anecdotal measures of innovation in equipment. These, however, by definition are subjective and subject to bias. One article by Will Townsend, an industry analyst, ranks the five major companies on current level of innovativeness in the market, and concludes that Ericsson and Samsung are in the lead, with Huawei and Nokia as followers, and ZTE as a laggard.[107]

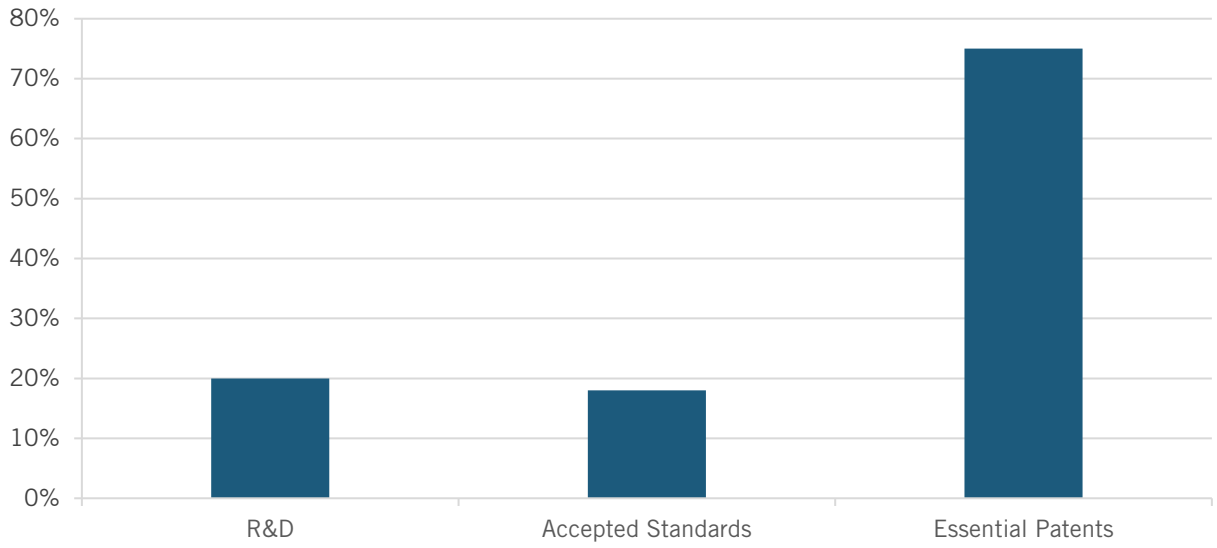
Net Impacts on Patents and Standards Contributions From Huawei and ZTE

What would be the estimated impact on patents and standards contributions if Huawei and ZTE did not exist? To estimate that, we use total telecommunications equipment sales for 2019.[108] We then use the share of global market for each company to calculate estimated equipment sales. Next, we divide the number of accepted standards contributions by sales for each of the four companies to estimated standards contribution per dollar of revenue. We then allocate all Huawei and ZTE revenues to Ericsson and ZTE based on their respective share of the global

market, and then multiply this new revenue by the standards contributions per billion of sales. The result shows that without Huawei and ZTE, total contributions increase from 15,991 to 18,949—an increase of 18 percent. (See figure 3.)

For patents, the calculation is similar. We use the measure of essential 5G patents obtained by each of the four companies. We then total the four scores and divide by four to come up with an average. We next divide each company's score by the average score for a ratio that will be greater or less than one. We multiply each company's ratio by the total number of 5G patents issued to it. We then measure the number of these patents per billion dollars in revenue. Next, we reallocate sales to Ericsson and Nokia from Huawei and ZTE according to their original share of revenue between the two companies. We then multiply the new total revenue for each of the two companies by the patent per billion dollars rate. This results—in the finding that if Ericsson and Nokia took Huawei and ZTE sales total essential 5G patents—would increase by 75 percent. (See figure 3.)

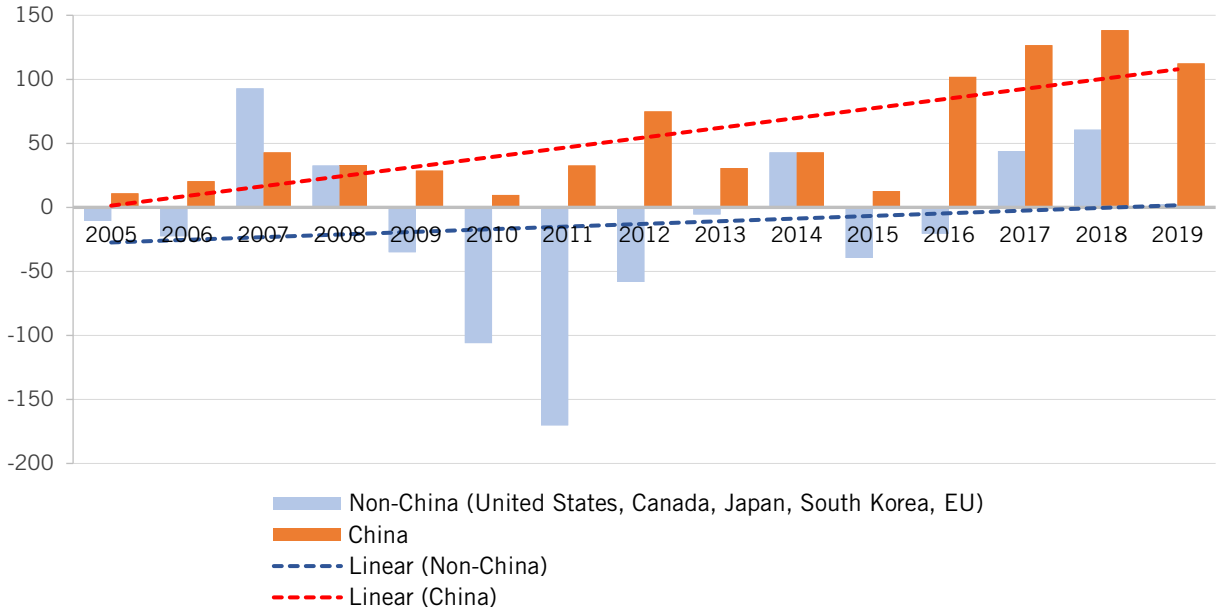
Figure 3: Estimated change in current Ericsson and Nokia innovation indicators if Huawei and ZTE did not exist[109]



Patent and Profit Trends

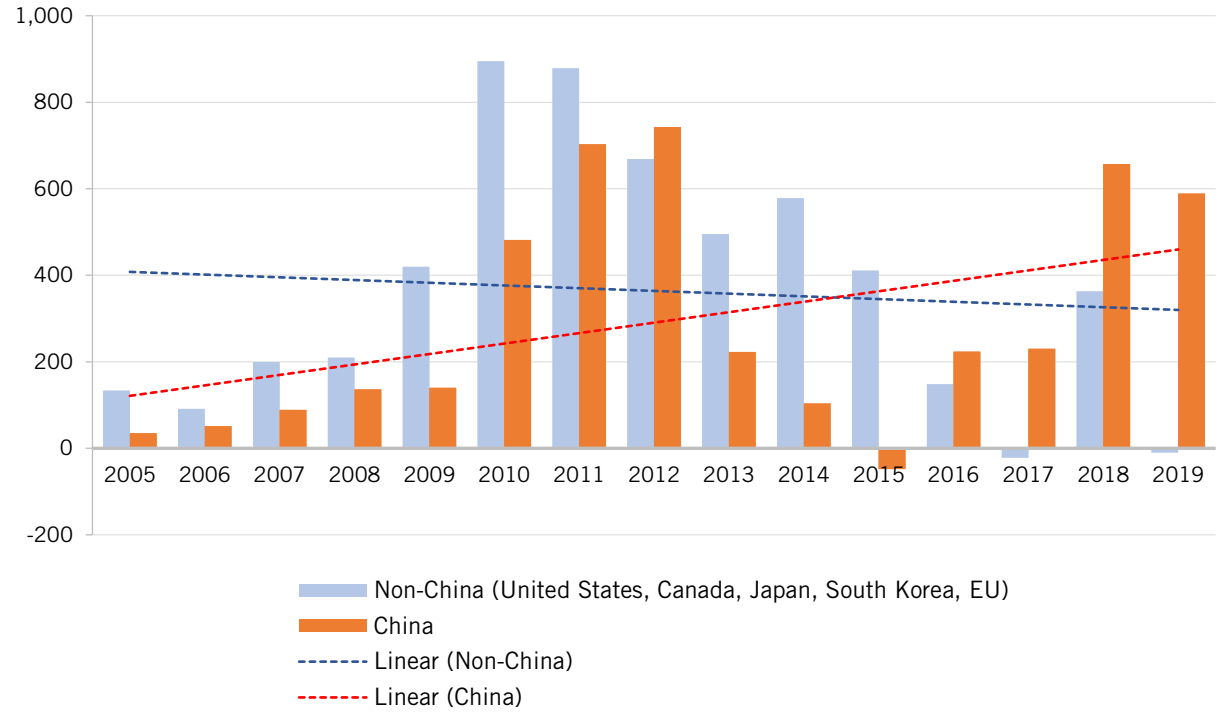
It also appears the rise of Chinese telecom equipment firms has slowed the pace of patenting relative to what it likely would have been otherwise. For example, the three-year running average trend from 2005 to 2019 in telephonic communication patents for organizations outside of China was up only significantly, in part because of the big declines after the Great Recession, while it was significantly upward for China as companies like Huawei and ZTE expanded. (See figure 4.)

Figure 4: H04M telephonic communication patents YOY increase (2005–2019) [110]



For wireless communication patents, the trend is slightly down non-Chinese countries, but up significantly for China. (See figure 5.)

Figure 5: H04W wireless communication patents YOY increase (2005–2019) [111]



Finally, as noted, there is considerable evidence that superior profits are critical to innovation. As William Baumol pointed out, "Prices above marginal costs and price discrimination become the norm rather than the exception because … without such deviations from behavior in the perfectly competitive model, innovation outlays and other unavoidable and repeated sunk outlays cannot be recouped."[112] Indeed, numerous studies of innovation industries have found that increased sales mean more R&D.[113] A study of European firms found that for high-tech firms, "Their capacity for increasing the level of technological knowledge over time is dependent on their size: the larger the R&D investor, the higher its rate of technical progress."[114]

According to profit data, the entry and subsequent dominance of Huawei reduced the profits rates of Ericsson and Nokia. Figure 6 and figure 7 show the profits for Ericsson and Nokia combined compared with Huawei, and the trend since 2004 is significantly down for Ericsson, and only modestly down for Huawei.

Figure 6: Profit rates of Huawei and Ericsson (2003–2018)[115]

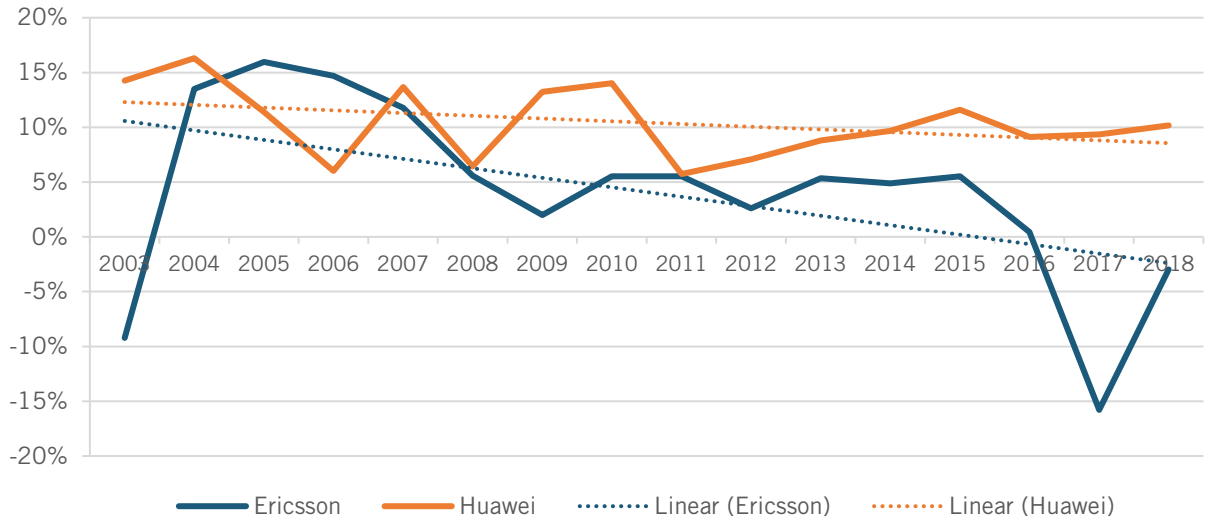
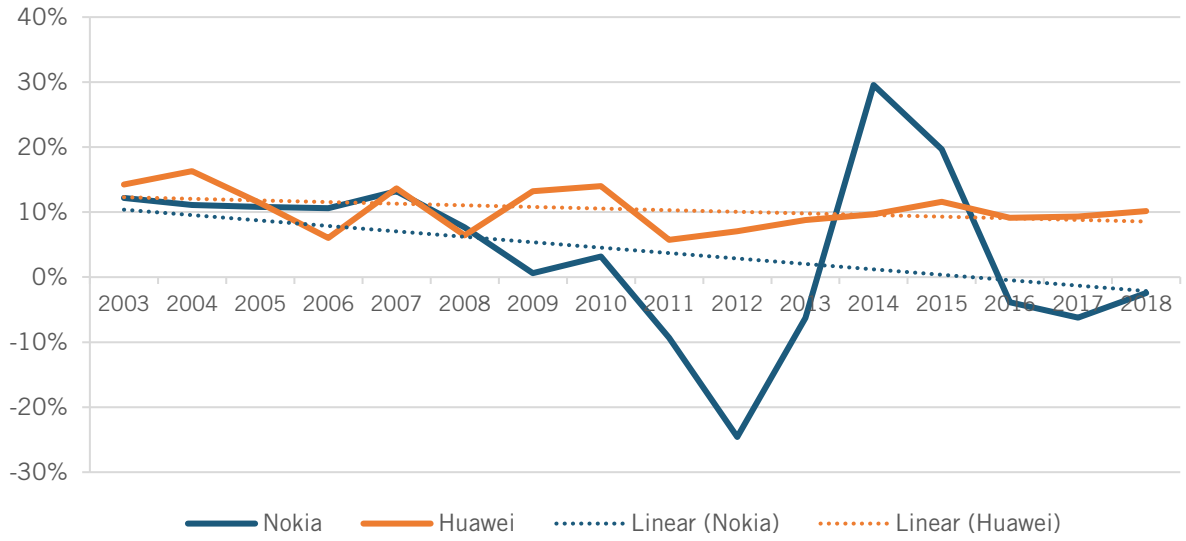


Figure 7: Profit rates of Huawei and Nokia (2003–2018)[116]



The effects on the R&D-to-sales ratio from 2008 to 2018 also show similar trends. Ericsson's growth rate is quite modest compared with Huawei's, while Nokia and Huawei appear to be on a similar trajectory. (See figure 8 and figure 9.)

Figure 8: Ericsson and Huawei R&D as a share of sales (2008–2018)[117]

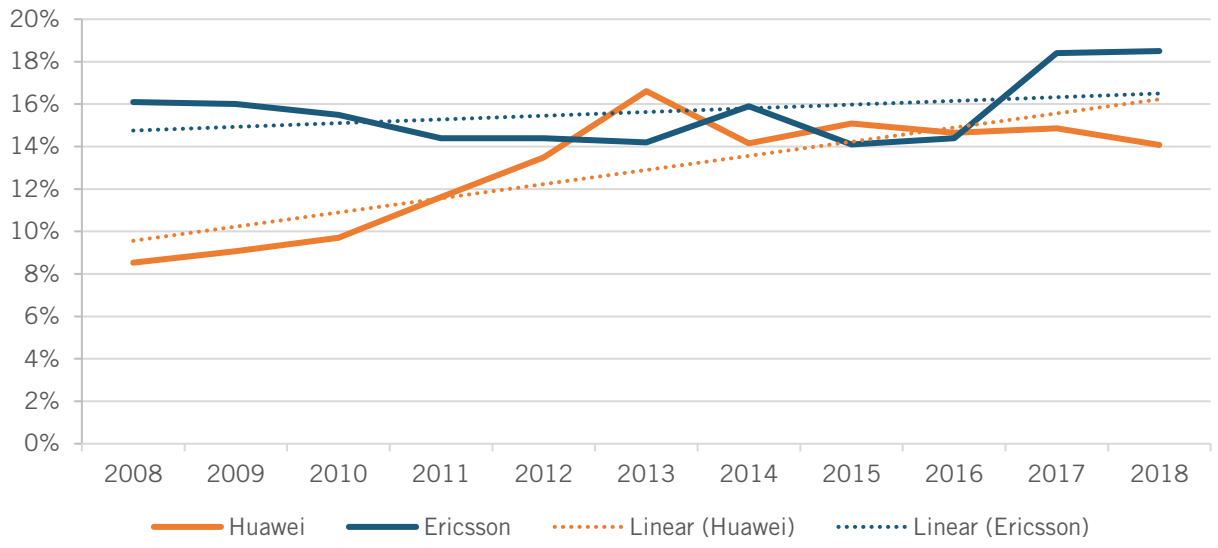
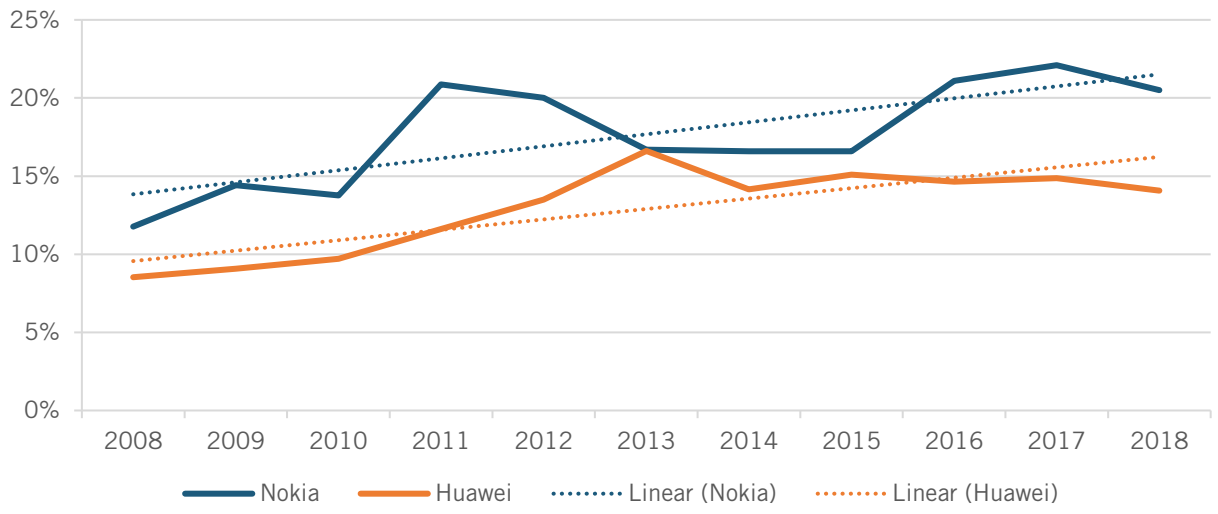


Figure 9: Nokia and Huawei R&D as a share of sales, 2008 to 2018[118]



None of this is to imply that there would be more innovation if there were only two major providers. Such a duopoly structure could very well decrease innovation by reducing the competitive forces facing companies. The real issue is the overall nature of competition—is it largely market-based with a level playing field, or distorted by government mercantilist policy? If Lucent and Nortel, for example, where still strong, independent players, then innovation is likely

to have been stronger. So, at one level, having a third and fourth competitor (Huawei and ZTE) has in all likelihood spurred Ericsson and Nokia to focus even more on innovation, especially as a way to differentiate themselves from the two Chinese companies that historically competed more on cost. But, with the inverted U, too much competition distorted by government mercantilist policies can reduce innovation. Indeed, there has long been a recognition of "the rule of three," the concept that in many advanced technology markets with high fixed costs and a need for scale, network economies have come to an equilibrium around three major players.[119] If Huawei and ZTE had not existed, it is highly likely the market today would have three to four major players: maybe Ericsson, Nokia, Nortel, and Samsung. And even going forward, if Huawei's and ZTE's global market shares were cut significantly, it is highly likely a third player, such as Samsung, would emerge—at least somewhat, provided there is an adequate and optimal level of competition, one that would be fair and market based.

RECOMMENDATIONS

Policymakers in market-based economies have three options to respond to China's systemic innovation-mercantilist practices that have and will continue to reduce global innovation in the telecom equipment industry: 1) the business version of the death penalty, 2) exoneration, or 3) the equivalent of imprisonment.

The Trump administration's ban on sales of key technology exports to Huawei is an attempt to impose the proverbial death penalty by starving the firm of inputs it needs. But this approach is unlikely to work, as Huawei appears to be able to procure the key technologies it needs for 5G systems elsewhere or produce them on its own. The main effect of this is to harm U.S. companies fighting for global market share. The same dynamic would occur if the administration goes forward with implementing Section 889, part B, of the National Defense Authorization Act which requires U.S. government contractors to ensure their global supply chain does not include gear from banned Chinese tech firms.[120] While well intentioned, this provision is virtually impossible for many firms to comply with as it sweeps up all suppliers globally using a vast array of technologies that could very well at some point in the supply chain targeted Chinese products. U.S. economic and trade policy should always follow the Hippocratic oath: do no harm to companies in America. This particular blunt force provision is medical malpractice as it harms the "patient" (the U.S. economy) while not killing the "disease" (Chinese telecom equipment firms).

Exoneration cannot be the answer, either, because it sends a clear signal to China that unfair, innovation-mercantilist actions over decades will be tolerated. This will only embolden China to extend and expand these unfair practices to other advanced industry sectors, including key technologies for the future.

Rather, "imprisonment" should be the answer. In other words, all democratic, market-based nations should exclude Huawei and ZTE from their markets while providing incentives for other nations to buy non-Chinese telecom gear. This will send a clear message to China that, going forward, systemic violations of trade rules will no longer be tolerated. To be clear, the issue is not whether there should be a variety of technology-based products in the world economy—some of high quality and perhaps higher cost, and some of lower quality and lower cost. The issue is whether these market offerings are generated mostly by market forces or by mercantilist policies and actions that are unfairly distortionary.

There are a number of steps trade-law-abiding, democratic nations should take—ideally, collectively—to address Chinese innovation-mercantilist policies in the telecom equipment industry.

Before addressing these, some will argue that the proper forum for addressing Chinese unfair practices in this sector is the WTO. Ideally, this would have been done in the 1980s and 1990s when unfair China policies laid the groundwork for the companies' emergence. But China wasn't a WTO member then. Nations could have done this in the 2000s when China was systemically violating WTO rules (such as no forcing technology transfers in exchange for market access, no dumping, and no subsidies), but not only did developed nations turn a blind eye to these challenges, on the rare occasions when they thought about acting, the Chinese government threatened retaliation against their companies. Moreover, the WTO itself is poorly structured to address Chinese "behind the border" innovation mercantilism.[121]

Now that the horses are out of the barn, WTO sanctions cannot effectively remedy that damage that has been done—even if countries could be persuaded to bring cases, and even if the WTO would side with these nations and allow effective sanctions to be imposed (all unlikely). Huawei and ZTE are simply too large and powerful. And Chinese government policies, even if by some miracle they could be marginally constrained by the WTO, will continue to give the companies an unfair advantage. As such, only joint action by market-oriented, democratic nations can address this challenge and remedy the wrong.

Exclude Huawei and ZTE From Allied Markets

The most important step free-trading nations can take is to expand the bans on Chinese telecom equipment sales. The United States and a number of other nations have banned Chinese telecom equipment in their networks because of security concerns. The issue of whether Chinese equipment can be trusted from a cybersecurity perspective is outside the scope of this analysis, but one effect of these bans is to work to level the playing field with China. As noted, the fact that China limits foreign equipment to a small share of the vast and fast-growing Chinese market gives Chinese firms a core advantage. As allied nations limit Chinese firms' share of their markets, they counter China's unfair advantage by enabling non-Chinese firms to gain market share.

EU nations should be less worried about a duopoly of Ericsson and Nokia and more worried about an emerging unnatural monopoly of Huawei.

The EU in particular needs to act, although it has been considering updating its International Procurement Instrument to achieve more reciprocity in government procurement with other nations, including China.[122] It should do this and include telecom equipment purchases by EU telecommunications providers in the instrument. And both the European Commission and national governments should work to impose 100 percent bans on Chinese telecom equipment in their markets.

Some European nations may be reluctant to do that, in part for purported competition concerns. For example, Orange Belgium CEO Michael Trabbia stated, "If we limit, with the U.S. trying to ban Chinese vendors, we will end up with only two vendors, and that is an issue." Huawei builds on these sentiments, as Victor Zhang, head of Huawei's U.K. operations, argued, "More suppliers

means greater competition, innovation and network reliability, and crucially ensures consumers have access to the best possible technology."[123]

But this not just shortsighted, it is wrong. As this report notes, more Chinese suppliers mean less innovation, not more. Moreover, there is a considerable likelihood that if EU nations do not put limits on Chinese firms' market access they will still end up with two vendors—one of them a globally dominant Huawei and the other an Ericsson or Nokia, whichever one survives continued unfair competition. EU nations should be less worried about a duopoly of Ericsson and Nokia and more worried about an emerging unnatural monopoly of Huawei.[124]

Moreover, far from creating a duopoly, limiting Huawei's market access in Europe is likely to make space for a third competitor, particularly Samsung—a company with a small but growing share in the 5G marketplace, and one that is significantly more innovative per dollar of sales than either Huawei or ZTE.

The Huawei and ZTE case is likely the most important case of our time in determining the future of the global economy: If market-based economies cannot cooperate to defend the spirit of the WTO and market principles here, then there is little chance they can ever effectively address Chinese innovation mercantilism.

Some will argue that limiting Chinese firms' access to markets—on either a security basis or on a trade-policy basis—will raise costs and slow the deployment of advanced networks, including 5G. But predatory subsidies and related practices should never be tolerated, even if the recipients (the customers of the protected firms) gain a short-term advantage. EU nations do not allow predatory pricing domestically because they realize it distorts competition—even if, in the short run, consumers benefit. They shouldn't allow foreign predatory policies either, in part because they are designed to gain market dominance, at which point pricing is no longer advantageous.

This is in many ways a classic prisoner's dilemma, where all rule-of-law, market-based economies are better off banning Chinese equipment (because doing so will lead to more innovation globally), but each individual country might be better off capitulating to get the benefit of subsidized Chinese gear. This pressure to defect from what is good for the world (not buying Chinese equipment) is particularly acute for middle- and lower-income nations, including in the EU, and nations whose wireless carriers are less well-capitalized, making them more susceptible to generous government-backed financial deals from China. As such, the Huawei and ZTE case is likely the most important case of our time in determining the future of the global economy: If market-based economies cannot cooperate to defend the spirit of the WTO and market principles here, then there is little chance they can ever effectively address Chinese innovation mercantilism.

In addition, when considering price, nations need to focus on quality-adjusted price. Often a slightly more expensive network is better for consumers because it is higher quality, with more features. Also, it is interesting that carriers in the two leading nations for 5G deployment, the United States and South Korea, do not use Huawei equipment. Moreover, a number of other nations that chose to not use Chinese 5G equipment for security reasons do not note significant increases in equipment costs.[125] To the extent nations worry bans or other limitations might lead to higher costs, they should allow carriers to expense the costs of new equipment in the first

year, rather than depreciating them over a number of years. This would reduce the after-tax cost of equipment and spur faster rollout and lower prices. Governments should also increase subsidies for wireline and wireless broadband rollout for rural areas, where needed.

One way to help carriers not be seduced by Chinese subsidies for telecom equipment is for governments to ensure competition policy enables needed economies of scale for broadband providers. Both wireline and wireless telecommunications are a scale business, both at the equipment and carrier level. Europe in particular needs larger carriers, as it has too many wireless mid-sized, undercapitalized carriers for it to take full advantage of the wireless revolution.[126] Indeed, the EU's fragmented market structure has played a substantial role in its slow adoption of 4G LTE technology. As a part of the digital single market for telecommunications, the EU should enable considerable consolidation in its mobile industry to allow firms to achieve appropriate economies of scale. The goal should be to eventually see dynamic competition between four to six firms covering virtually all of Europe. This would allow stronger balance sheets for EU carriers, making it easier for them to resist the seduction of lower-priced Chinese offerings, particularly ones that come with generous financing and no payments for several years, or even payments only made if the carrier adds a certain number of subscribers.

Finally, policymakers also need to remember that competition is a means, not an end. And one of the principal goals of competition policy is robust innovation. Enabling less-innovative Chinese producers backed by unfair mercantilist policies more market share means that over the medium and long term, consumers do not get access to the best possible technology.

Actively Support the Rollout of Advanced Broadband Networks

Nations should do more to spur the rollout of advanced broadband networks, including significantly streamlining and lowering the cost of permitting for cell sites; ensuring government is a lead adopter; providing a favorable tax environment for investing in equipment; and supporting the adoption of 5G services in cities and sectors such as utilities, manufacturing, transportation, and others.[127] Ideally these networks would feature equipment with openly defined interfaces, which would reduce the vendor lock-in that has been especially problematic with Huawei's 4G radio equipment.[128]

Counter China's Aggressive Efforts to Support Its National Champions in Developing Economies

Some will argue that China has also benefited global innovation in the Internet and wireless space by subsidizing deployment of advanced telecom equipment, particularly in less-developed nations, such as in Africa.[129] This is no doubt true, but the response should not be to continue to turn a blind eye to unfair Chinese practices, including excess and unfair export financing. Allied nations should establish their own well-funded joint development bank, or at least coordinate among themselves and significantly expand export financing for telecom and Internet equipment, and use that to counter China's deep-pocketed influence in developing regions. In particular, the aid should be targeted to nations with lower levels of corruption and more-democratic governments.

In addition, OECD should step up efforts to police excessive Chinese export financing in this industry. OECD has developed the Aircraft Sector Understanding, which represents a "gentlemen's agreement" with regard to officially supported export credits relating to civil aircraft.[130] They should adopt a similar approach and measure China's compliance with it.

To the extent China is violating the agreement, OECD countries should put in place remedies and responses, including limits on domestic market access, and expanding their own financing packages.

Finally, allied governments should tie foreign aid to countries' decisions to ban Chinese telecom equipment purchases going forward. Too many nations receiving significant amounts of allied foreign aid continue to buy equipment from Chinese telecom firms.

Work Collectively to Counter China's Unfair Practices, Including at WTO

As noted, it is in many ways too late to counter Chinese mercantilist practices in this industry with WTO action. China systemically violated WTO rules and norms both before and after it joined the organization in order to develop globally competitive firms that are now somewhat less reliant on direct government aid. As such, strong WTO action comes only after the horses have already left the barn. Indeed, too often, WTO cases brought in advanced technology sectors such as solar panels represent a coroner's inquest, with the complainant enterprise(s) dead or dying, unable to withstand massive levels of Chinese innovation mercantilism, including practices enumerated in this report, such as excessive subsidization, intellectual property theft, and imbalanced market access rules. Nonetheless, allied nations should supplement their own domestic actions by cooperating in bringing WTO cases against China for unfair practices in this industry, including ongoing subsidies.

SUMMARY

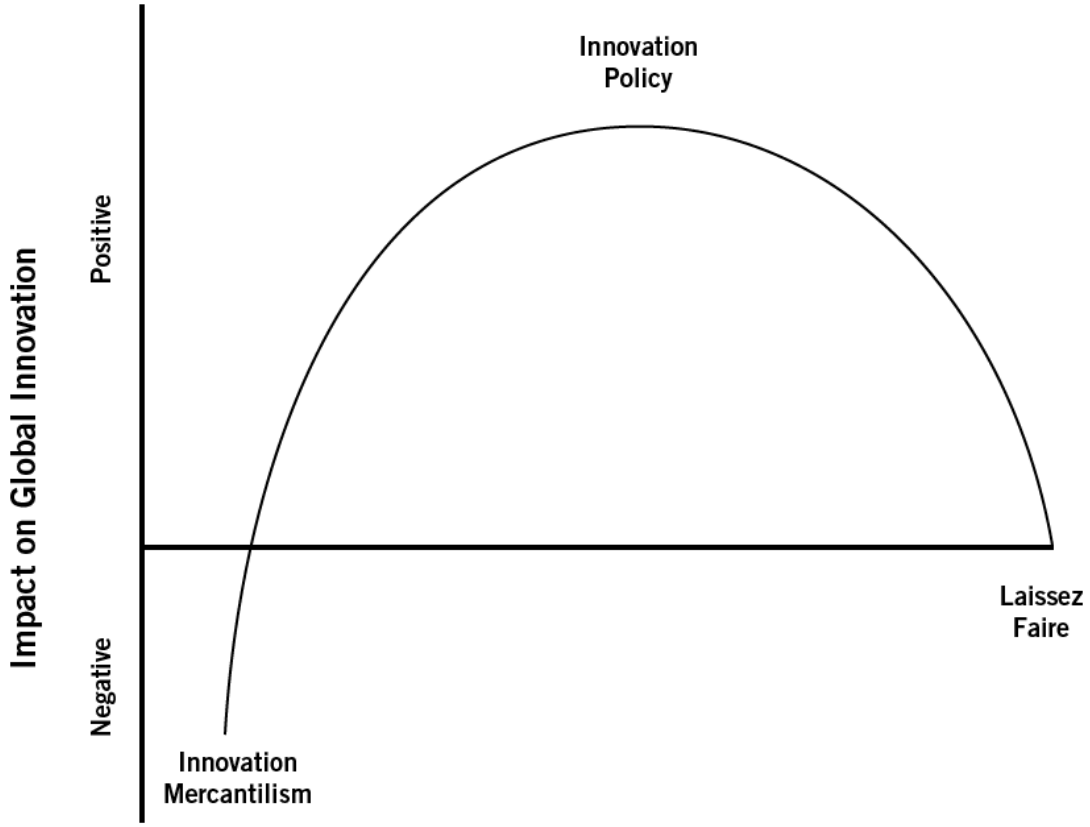
This analysis suggests that, on net, Chinese-government policies toward the telecommunications equipment industry have reduced global innovation by enabling less-innovative Chinese companies to take market share from more innovative, non-Chinese companies. This has led to either the destruction of those companies (as in the case of Nortel), or to the rate of innovation in remaining companies slowing from what it otherwise would have been.

This is not to say some Chinese policies do not spur innovation in the industry. For example, Chinese 5G policies (which include provision of adequate spectrum), streamlining local deployment of 5G cells, and supporting 5G-enabled infrastructure such as smart cities promote 5G innovation by making the market larger, thereby enabling equipment companies to increase revenues. But Chinese-government policies limit more innovative foreign companies from accessing that market.

Global innovation would be maximized with a regime that combines some of the positive aspects of Chinese policy with the positive aspects of market-economy policy.

Chinese R&D policy, including R&D grants to Huawei and ZTE, generous R&D tax incentives, and lower corporate tax rates on R&D-intensive firms, also spur innovation.[131] In addition, Chinese policies enable scale, which is critical in R&D and technology-intensive industries. The Chinese government not only allows their firms to get big, it encourages it, which in turn gives these firms greater capabilities to innovate. Finally, Chinese education policies that train large numbers of reasonably skilled and reasonably priced engineers, particularly those focused on development, allow Chinese companies to deploy a larger number of engineers toward solving problems than companies in developed nations.

Figure 10: Economic and trade-policy regimes and their impact on global innovation



Innovation Mercantilism	Innovation Policy	Laissez Faire
Protected markets	Reciprocal market access	Open markets
IP theft/forced tech transfer	Support for wireline and wireless rollout and adoption	No subsidies/neutral tax code
Production subsidies	Targeted tax incentives and R&D funding	
Excess export subsidies		

This gets to a key point: Global innovation would be maximized with a regime that combines some of the positive aspects of Chinese policy with the positive aspects of developed market-economy policy. In other words, neither laissez faire, free-market regimes nor innovation mercantilist, state-capitalist regimes maximize global innovation. (See figure 10.) What is needed is widespread adoption of "innovation policy" regimes. By that we mean economic systems that allow market forces to play the major role in determining investment and success (markets that let domestic and foreign firms compete fairly; no IP theft or coerced technology transfer; and limited subsidies beyond support for pre-competitive research), while at the same time government policies that apply to all firms in the telecom equipment industry, regardless of nationality (assuming reciprocity by firm's home country), to foster a supportive environment with

adequate factor conditions, including robust government funding for pre-competitive research, a generous R&D tax incentive, and government support for science and engineering talent. In addition, providing adequate wireless spectrum, policies to deploy broadband to more places, and support adoption by low-income households; and policies to spur adoption of 5G services, including supporting smart cities, smart transportation, and other related application areas, all support innovation in the industry.[132]

Notwithstanding this, some will argue that policymakers should let "the market" work, and that carriers should choose to buy equipment from whatever company provides the best value. Emblematic of this view is the Cato Institute's John Tammy, who wrote, "[I]f Huawei can help Americans reach a 5G future sooner than American companies can, why should we care?"[133] There are two reasons we should care. The first, as noted, is that Huawei didn't get to this position on the basis of the free trade and free markets Tammy has advocated. Letting it gain even more market share sends a clear signal that unfair market and trade practices will have no consequences or penalties. The second is more important. As this study has shown, every dollar spent on Huawei (or ZTE) versus more-innovative companies such as Ericsson, Nokia, or Samsung means less—not more—innovation. So, the real question is not whether Huawei can help nations reach a 5G future faster—it probably can, in part because the Chinese government is subsidizing the sales. The real question is whether Huawei can help nations reach a "6G future" fast—in other words, help maximize innovation in the telecom equipment industry. The answer to that question is a decisive "no!"

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ENDNOTES

1. For a discussion of 5G and 5G policy see Doug Brake, "A U.S. National Strategy for 5G and Future Wireless Innovation" (ITIF, April 27, 2020), https://itif.org/publications/2020/04/27/us-national-strategy-5g-and-future-wireless-innovation.
2. Kenneth J. Arrow, "Economic Welfare and the Allocation of Resources for Invention," in *Essays in the Theory of Risk-Bearing*, ed. Kenneth J. Arrow (Amsterdam: North-Holland, 1971), 144–160.
3. Myeongwan Kim, "Does Import Competition Reduce Domestic Innovation? Evidence from the 'China Shock' and Firm-Level Data on Canadian Manufacturing" (CSLS, March 2019), 2, http://www.csls.ca/reports/csls2019-03.pdf.
4. White House, Council of Economic Advisers, "Benefits of Competition and Indicators of Market Power," Council of Economic Advisors Issue Brief, ObamaWhiteHouseArchives.gov, May 2016, 3, https://obamawhitehouse.archives.gov/sites/default/files/page/files/20160502_competition_issue_brief_updated_cea.pdf.
5. William J. Baumol, *The Free-Market Innovation Machine* (Princeton, NJ: Princeton University Press, 2002), 287.
6. Ibid.
7. Phillip Aghion et al., "Competition and Innovation: an inverted-U relationship," *Quarterly Journal of Economics,* 120 (2005), 701; F.M. Scherer, "Market Structure and the Employment of Scientists and Engineers," *American Economic Review,* 57, no. 3 (1967), 524–531.
8. Aamir Rafique Hasmi, "Competition and Innovation: The Inverted-U relationship Revisited," *Review of Economics and Statistics*, (2013), 1653–1668, http://ssrn.com/abstract=2012918.
9. Toshihiko Mukoyama, "Innovation, Imitation, and Growth with Cumulative Technology," *Journal of Monetary Economics*, 50, no. 2 (2003), 361–380.
10. Bronwyn H. Hall, "Investment and research and development at the firm level: Does the Source of Financing Matter?" (working paper, NBER, 1992; Lorne Switzer, "The determinants of industrial R&D: A Funds Flow Simultaneous Equation Approach," *Review of Economics and Statistics*, 66 no. 1, (1984), 163–168; Cited in George Symeonidis, "Innovation, Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes," (working paper, OECD Economic Department no. 161, 1996), 15; Matilde Bombardini, Bingjing Li, and Ruoying Wang, "Import Competition and Innovation: Evidence from China" December 4, 2017, 5, http://www7.econ.hit-u.ac.jp/cces/trade_conference_2017/paper/matilde_bombardini.pdf.
11. Robert D. Atkinson, *Enough is Enough: Confronting Chinese Innovation Mercantilism* (ITIF, February 2012), http://www2.itif.org/2012-enough-enough-chinese-mercantilism.pdf.
12. Carl Shapiro, "Competition and Innovation: Did arrow Hit the Bull's Eye?" in *The Rate and Direction of Inventive Activity Revisited*, ed. Josh Learner and Scott Stern, (Cambridge: NBER Books, 2012), 361–404.
13. Joseph Schumpeter, Capitalism, Socialism and Democracy (New York: Harper, 1975), 82–85.
14. Frankfurt School-UNEP Centre/BNEF, Global Trends in Renewable Energy Investment" (2013), http://www.unep.org/pdf/GTR-UNEP-FS-BNEF2.pdf.
15. Adam B. Jaffe, Josh Lerner, and Scott Stern, "Innovation Policy and the Economy," NBER (August 2006), vol. 6, 205, http://www.nber.org/books/jaff06-1; Richard Gilbert, "Looking for Mr. Schumpeter: Where Are We in the Competition-Innovation Debate?" NBER (August 2005), http://www.nber.org/chapters/c0208.
16. William W. Lewis, *The Power of Productivity: Wealth, Poverty, and the Threat to Global Stability* (Chicago: University of Chicago Press, 2005), http://www.press.uchicago.edu/Misc/Chicago/476766.html.

17. Alberto F. De Toni, *International Operations Management: Lessons in Global Business* (New York: Routledge, 2016).
18. Sharon Gaudin, "The transistor: The most important invention of the 20th century?" *Computerworld*, December 12, 2007, https://www.computerworld.com/article/2538123/the-transistor--the-most-important-invention-of-the-20th-century-.html.
19. Thomas J. Luria, *The Fall of Telecom*, 2007.
20. Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (New York: Penguin Books, 2012).
21. Ibid, 270.
22. Christopher Rhoads and Charles Hutzler, "China's Telecom Forays Squeeze Struggling Rivals," *The Wall Street Journal*, September 8, 2004, https://www.wsj.com/articles/SB109459495670311660.
23. World Trade Organization, *International Trade Statistics 2009* (Geneva: WTO, 2009) , 90, https://www.wto.org/english/res_e/statis_e/its2009_e/its2009_e.pdf.
24. Data provided by email exchange with the Dell'Oro Group, May 29, 2020, https://www.delloro.com/.
25. Peter Nolan, *China and the Global Business Revolution*, (London: Palgrave Macmillan, 2001), 795.
26. Ibid, 863.
27. *The Industrial Reorganization Act: Hearings before the Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary United States Senate*, 93rd Cong. (1973).
28. Qing Mu and Keun Lee, "Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China," *Research Policy*, vol. 3, iss. 6, (2005) 759–783, https://doi.org/10.1016/j.respol.2005.02.007.
29. Xiaobai Shen, *The Chinese Road to High Technology: A Study of Telecommunications Switching Technology in the Economic Transition* (New York: St. Martin's Press, 1999), 64.
30. Ibid.
31. Nolan, *China and the Global Business Revolution*, 796.
32. Ji Li, Kevin Lam, and Gongming Quian, "High-Tech Industries and Competitive Advantage in Emerging Markets: A Study of Foreign Telecommunications Equipment firms in China*," The Journal of High Technology Management Research*, vol. 10, no. 2, 285, 299, 312.
33. Ulaş Emiroğlu, "Catch-up with Generative State: Lessons from Chinese Telecom Equipment Industry" (working paper, METU-TEKPOL) , 6, 9, https://stps.metu.edu.tr/en/system/files/stps_wp_1503.pdf.
34. Peilei Fan, "Made in China: The Rise of the Chinese Domestic Firms in the Information Industry," Massachusetts Institute of Technology, Dept. of Urban Studies and Planning, September 2003.
35. Luria, *The Fall of Telecom*, 126.
36. David Bennett, "Nordica and Danaudio in China," in Business Case Studies in Operations Management (Auckland: Pearson Education, 2002), 253–262.
37. William Hannas, James Mulvenon, and Anna Puglisi, *Chinese Industrial Espionage: Technology Acquisition and Military Modernization* (Asian Security Studies), (New York: Routledge, 2013), 57.
38. Mu and Lee, "Knowledge diffusion, market segmentation and technological catch-up."
39. Ibid; Zixiang Alex Tan, "Product cycle theory and telecommunications industry - Foreign direct investment, government policy, and indigenous manufacturing in China," *Telecommunications Policy* (2002), https://doi.org/10.1016/S0308-5961(01)00051-9; Eric Harwit, "Building China's Telecommunications Network: Industrial Policy and the Role of Chinese State-Owned, Foreign and Private Domestic Enterprises," *The China Quarterly*, no. 190, (June 2007), 311–332, https://www.jstor.org/stable/20192772?seq=1.

40. Mu and Lee, "Knowledge diffusion, market segmentation and technological catch-up."
41. Ibid.
42. Ibid.
43. Xiaobai Shen, *The Chinese Road to High Technology: A Study of Telecommunications Switching Technology in the Economic Transition* (London: Palgrave Macmillan, 1999), 153.
44. Kun Jiang et al., "International Joint Ventures and Internal vs. External Technology Transfer: Evidence from China" (working paper, NBER, 2018), 37, https://www.nber.org/papers/w24455.
45. Evan S. Medeiros et al., "The Digital Triangle": A New Defense-Industrial Paradigm?" in *A New Direction for China's Defense Industry*, (RAND Corporation, 2005), https://www.jstor.org/stable/pdf/10.7249/mg334af.12.pdf.
46. Staff Research Study, "Telecommunications Equipment: U.S. Performance in Selected Major Markets," (Washington, D.C.: U.S. International Trade Commission, December 1998).
47. Ulaş Emiroğlu, "Catch-up with Generative State: Lessons from Chinese Telecom Equipment Industry" (working paper, METU-TEKPOL), 9, https://stps.metu.edu.tr/en/system/files/stps_wp_1503.pdf.
48. Mu and Lee, "Knowledge diffusion, market segmentation and technological catch-up."
49. China Economic and Security Review Commission, "China's Industrial Policy and its Impact on U.S. Companies, Workers and the American Economy" (2009), 129, https://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1647&context=key_workplace.
50. Marc Bacchetta and Bijit Bora, *Industrial Tariff Liberalization and the Doha Development Agenda*, World Trade Organization (Geneva: 2003), https://www.wto.org/english/res_e/booksp_e/discussion_papers_e.pdf.
51. Quoted in Michael O. McCarthy, "Background Material for US-China Economic and Security Review Commission,"(June 6, 2012), 8.
52. Melanie Mingas, "Huawei, ZTE and Ericsson win China Mobile 5G contracts," Capacity, April 3, 2020, https://www.capacitymedia.com/articles/3825224/huawei-zte-and-ericsson-win-china-mobile-5g-contract.
53. Philip Blenkinsop, "EU holds fire on ZTE, Huawei Telecom Trade Case," *Reuters,* October 9, 2012, https://www.reuters.com/article/us-eu-china-trade/eu-holds-fire-on-zte-huawei-telecom-trade-case-idUSBRE89810V20121009.
54. "Monthly Customer Data," China Mobile, https://www.chinamobileltd.com/en/ir/operation_m.php.
55. Scott Bicheno, "Huawei threatened to pull investment from Denmark in response to new screening law," *Telecoms.com,* May 14, 2020, https://telecoms.com/504302/huawei-threatened-to-pull-investment-from-denmark-in-response-to-new-screening-law/.
56. Phil Garton and Jennifer Chang, "The Chinese currency: how undervalued and how much does it matter?" Australian Government Treasury, December 12, 2005, https://treasury.gov.au/publication/economic-roundup-spring-2005/the-chinese-currency-how-undervalued-and-how-much-does-it-matter; China Power Team, "Is the Renminbi undervalued or overvalued?" *China Power*, February 11, 2016, https://chinapower.csis.org/renminbi-undervalued/.
57. Jodi Wu, Cori A. Lable, and Gerald Lam, "A Shift in U.S. FCPA Policy—Should Chinese Companies be Worried?" *Bloomberg Law,* June 10, 2019, https://www.kirkland.com/publications/article/2019/06/a-shift-in-us-fcpa-policy_should-chinese-companies.

58. Masood Farivar, "Bribery, Corruption Charges Follow Huawei Around World," *VOA,* February 11, 2019, https://www.voanews.com/east-asia-pacific/bribery-corruption-charges-follow-huawei-around-world.

59. Council on Ethics, The Government Pension Fund Global, Recommendation to exclude ZTE Corp. from the Government Pension Fund Global https://nettsteder.regjeringen.no/etikkradet3/files/2017/05/ENG-Tilr%C3%A5dning-ZTE-24.-juni-2015-ENGELSK-amended-Nov.-2016.pdf

60. RWR Advisory Group, A Transactional Risk Profile of Huawei" February 13, 2018. https://www.rwradvisory.com/wp-content/uploads/2019/03/RWR-Huawei-Risk-Report-2-13-18.pdf, p. 20.

61. Ibid.

62. Duanjie Chen, "Huawei Risk is a China Risk: Why Canada Needs to Ban Huawei's Involvement in 5G" (MLI, March 2020), https://macdonaldlaurier.ca/files/pdf/20200309_MLI_Huawei_Risk_Chen_PAPER_FWeb.pdf?mc_cid=9526a0928c&mc_eid=9d0ff66926.

63. Bruce Gilley, "Huawei's Fixed Line to Beijing," *Far Eastern Economic Review*, December 28, 2000–January 4, 2001, 96, https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/130215_competitiveness_Huawei_casestudy_Web.pdf.

64. Chuin-Wei Yap, "State Support Helped Fuel Huawei's Global Rise," *The Wall Street Journal*, December 25, 2019, https://www.wsj.com/articles/state-support-helped-fuel-huaweis-global-rise-11577280736.

65. Quoted in Michael O. McCarthy, "Background Material for US-China Economic and Security Review Commission,"(June 6, 2012), 8.

66. Christopher Balding, "Financing 5G Rollout in the Face of Nation State Security Threats and Non-Market Subsidies: Policy Options for States to Address Cost Concerns," Fulbright University (February 2020), 3, https://ssrn.com/abstract=3537463.

67. Ibid, 9.

68. Ryan Mcmorrow, "Huawei a key beneficiary of China subsidies that US wants ended," *Phys.org*, May 30, 2019, https://phys.org/news/2019-05-huawei-key-beneficiary-china-subsidies.html.

69. Xiaofei Liu, 2016. "Zhang Yansheng: 'Without BRI, There Wouldn't Be Huawei,'"Finance.China.com, September 2, 2016, Last accessed on December 31, 2019, http://finance.china.com.cn/news/special/2016g20summit/20160902/3889560.shtml.

70. Joseph Marks, "The Cybersecurity 202: China's big weapon in the Huawei fight: Money," *The Washington Post*, May 29, 2019, https://www.washingtonpost.com/news/powerpost/paloma/the-cybersecurity-202/2019/05/29/the-cybersecurity-202-china-s-big-weapon-in-the-huawei-fight-money/5cedd8f11ad2e52231e8e836/.

71. Ellen Nakashima, "U.S. pushes hard for a ban on Huawei in Europe, but the firm's 5G prices are nearly irresistible," *The Washington Post*, May 29, 2019, https://www.washingtonpost.com/world/national-security/for-huawei-the-5g-play-is-in-europe--and-the-us-is-pushing-hard-for-a-ban-there/2019/05/28/582a8ff6-78d4-11e9-b7ae-390de4259661_story.html.

72. Ibid.

73. Jeff Ferry, "5G Wireless: Pallone-Walden Bill Is a Good Start But We Need A More Aggressive Strategy," *Coalition for a Prosperous America,* May 11, 2020, https://www.prosperousamerica.org/5g_wireless_pallone_walden_bill_is_a_good_start_but_we_need_a_more_aggressive_strategy.

74. Andrew Backover, "Feds: Trio stole Lucent's trade secrets," *USA TODAY*, May 5, 2001, http://usatoday30.usatoday.com/life/cyber/tech/2001-05-03-lucent-scientists-china.htm.
75. Phil Wahba, Helen Chernikoff, and Sinead Carew, "Motorola sues Huawei, Lemko for trade secret theft," *Reuters*, July 21, 2010, https://www.reuters.com/article/motorola-huawei/motorola-sues-huawei-lemko-for-trade-secret-theft-idUSN2119138220100722.
76. Jeff Ferry, "Top Five Cases of Huawei IP Theft and Patent Infringement," *Coalition for a Prosperous America*, December 13, 2018, https://www.prosperousamerica.org/top_five_cases_of_huawei_ip_theft_and_patent_infringement.
77. Ibid.
78. United States of America v. Huawei Technologies, U.S. Eastern District of New York, Cr. No. 18-457 (S-3) (AMD), 2020, 4.
79. Ibid.
80. Duanjie Chen, "Huawei Risk is a China Risk: Why Canada Needs to Ban Huawei's Involvement in 5G" (MLI, March 2020), https://macdonaldlaurier.ca/files/pdf/20200309_MLI_Huawei_Risk_Chen_PAPER_FWeb.pdf?mc_cid=9526a0928c&mc_eid=9d0ff66926.
81. Sara D. Davis, "Nortel hacked to pieces," *Financial Post*, February 25, 2012, https://business.financialpost.com/technology/nortel-hacked-to-pieces.
82. Tom Blackwell, "Exclusive: Did Huawei bring down Nortel? Corporate espionage, theft, and the parallel rise and fall of two telecom giants," *National Post*, February 20, 2020, https://nationalpost.com/news/exclusive-did-huawei-bring-down-nortel-corporate-espionage-theft-and-the-parallel-rise-and-fall-of-two-telecom-giants.
83. Iain Marlow, "Nortel turned to RCMP about cyber hacking in 2004, ex-employee says," *The Globe and Mail*, February 15, 2012, https://www.theglobeandmail.com/technology/tech-news/nortel-turned-to-rcmp-about-cyber-hacking-in-2004-ex-employee-says/article534295/.
84. Brian Fung, "How China's Huawei took the lead over U.S. companies in 5G technology," *The Washington Post*, April 10, 2019, https://www.washingtonpost.com/technology/2019/04/10/us-spat-with-huawei-explained/.
85. Chen, "Huawei Risk is a China Risk."
86. For example, on patent intensity, Samsung is seven times as innovative as Nokia (which is ahead of the other three companies) and has 70 percent greater standards contributions intensity than Ericsson. However, this is in part because their market share is quite small (3 percent) and it is possible that the company is funding this R&D out of revenues from other lines of business in the company.
87. Jamie Davies, "Ericsson and Nokia up their R&D game to compound Huawei misery," *Telecoms.com,* August 28, 2019, https://telecoms.com/499382/ericsson-and-nokia-up-their-rd-game-to-compound-huawei-misery/.
88. Source: Ericsson, Huawei, Nokia, and ZTE company annual reports.
89. It should be noted that the telecommunications business accounts for only about 35 percent of Huawei revenues—the rest of devices and enterprise systems, whereas a much greater share of revenues for Ericsson and Nokia are from telecom equipment.
90. Jamie Davies, "Ericsson and Nokia up their R&D game to compound Huawei misery."
91. Because Huawei does not separate out network sales form total sales, we estimate network sales are 35 percent of total sales.
92. "Who is leading the 5G patent race?" *iPlytics,* November 20, 2019, https://www.iplytics.com/report/who-is-leading-the-5g-patent-race/.

93. This data is provided by the business consultancy Dell'Oro Group. We take the global market share of total global telecom equipment purchases for these four countries, and then add these shares together for their collective global market share. We then divided their actual market share with their market share relative to the other three companies only. The results are: 41 percent for Huawei, 24 percent for Nokia, 21 percent for Ericsson, and 15 percent for ZTE.
94. Pete Bell, "Huawei: No Way or All the Way?" *TeleGeography* blog, February 21, 2019, https://blog.telegeography.com/huawei-sanction-violations-explained.
95. We do not use R&D as the denominator because companies differ in what share of sales they invest in R&D, and how efficient their R&D is at producing innovations, in this case patents. Rather, we want to measure how innovative companies controlling for total sales.
96. Matthew Nobel, Jane Mutimear, and Richard Vary, "Determining which companies are leading the 5G race," *IAM* (2019), https://www.twobirds.com/~/media/pdfs/news/articles/2019/determining-which-companies-are-leading-the-5g-race.pdf.
97. "Examining Apple's Blockbuster Purchase of Intel's Assets," LexisNexis, July 30, 2019, https://www.ipwatchdog.com/wp-content/uploads/2019/07/SLIDE-DECK-apple-intel-07-30-2019-FINAL.pdf.
98. "Interactive: Patent Power 2017," IEE Spectrum, https://spectrum.ieee.org/static/interactive-patent-power-2017.
99. Matthew Nobel, Jane Mutimear, and Richard Vary, "Determining which Companies are Leading the 5G Race."
100. The OECD defines purchasing power parities as the rates of currency conversion that try to equalize the purchasing power of different currencies by eliminating the differences in price levels between countries; "Purchasing Power Parities (PPP)," OECD Data, https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm.
101. ITIF calculations.
102. Takahiro Shibuya, "Patent king Huawei lags Intel and Qualcomm in quality, study finds," *Nikkei Asian Review,* October 27, 2019, https://asia.nikkei.com/Spotlight/Datawatch/Patent-king-Huawei-lags-Intel-and-Qualcomm-in-quality-study-finds.
103. "Who is leading the 5G patent race?" *iPlytics*.
104. Ibid.
105. A Minneapolis Federal study estimates fully half of IP "possessed" by Chinese firms originally came from foreign ones: Thomas J. Holmes, Ellen R. McGrattan, and Edward C. Prescott, "The Costs of Quid Pro Quo," Federal Reserve Bank of Minneapolis (January 2015), https://www.minneapolisfed.org/research/economic-policy-papers/the-costs-of-quid-pro-quo.
106. Ibid.
107. Will Townsend, "Who Is 'Really' Leading in Mobile 5G, Part4: Infrastructure Equipment Providers," *Forbes*, July 19, 2019, https://www.forbes.com/sites/moorinsights/2019/07/19/who-is-really-leading-in-mobile-5g-part-4-infrastructure-equipment-providers/#4616db8d9130
108. This is an estimated $198 billion; "Communications equipment market size by product category from 2014 to 2019," Statista Research Department, Mar 2, 2020, https://www.statista.com/statistics/292210/global-spendings-it-communications-equipment/.
109. ITIF calculations.
110. Ibid.
111. Ibid.
112. Robert D. Atkinson and Michael Lind, *Big Is Beautiful: Debunking the Myth of Small Business* (Massachusetts MIT Press, 2018), 54.

113. Ibid, 55.
114. Ibid 55.
115. Huawei, Huawei Annual Report, 2006–2019, https://www.huawei.com/us/press-events/annual-report, accessed May 13, 2020; Telefonaktiebolaget LM Ericsson, Ericsson Annual Report, 1996-2019, https://www.ericsson.com/en/about-us/history/sources/annual-reports, accessed May 13, 2020.
116. Ibid.
117. Ibid.
118. Ibid.
119. Adam Thierer, "The Rule Of Three: The Nature of Competition In The Digital Economy," *Forbes*, June 29, 2012, https://www.forbes.com/sites/adamthierer/2012/06/29/the-rule-of-three-the-nature-of-competition-in-the-digital-economy/#365193d77a04.
120. "Dread over impending anti-Huawei law grows," South China Morning Post, June 10, 2020. https://www.scmp.com/tech/big-tech/article/3088457/dread-over-impending-anti-huawei-law-grows-us-companies
121. Mark Wu, "The 'China Inc.' Challenge to Global Trade Governance," *Harvard International Law Journal*, Vol. 57, no. 2, pp: 261-324. https://chinaipr2.files.wordpress.com/2018/06/hli210_crop-mark-wu.pdf.
122. Philip Blenkinsop, "Brussels pushes EU leaders to play public tender card against China," *Reuters,* March 20, 2019, https://www.reuters.com/article/us-eu-china/brussels-pushes-eu-leaders-to-play-public-tender-card-against-china-idUSKCN1R11O4.
123. Leo Kelion, "Huawei: What would happen if the UK ditched the Chinese firm?" *BBC,* May 26, 2020, https://www.bbc.com/news/technology-52797859.
124. Jeff Ferry, "5G Wireless: Pallone-Walden Bill Is a Good Start But We Need A More Aggressive Strategy," Coalition for a Prosperous America, May 11, 2020, https://www.prosperousamerica.org/5g_wireless_pallone_walden_bill_is_a_good_start_but_we_need_a_more_aggressive_strategy.
125. Balding, op. cit.
126. Doug Brake, "Spectrum Policy and the EU Digital Single Market: Lessons from the United States" (ITIF, December 2015), https://itif.org/publications/2015/12/07/spectrum-policy-and-eu-digital-single-market-lessons-united-states.
127. See Doug Brake, "A U.S. National Strategy for 5G and Future Wireless Innovation."
128. Ibid.
129. W. Gyude Moore, "African countries should stay loyal to China's troubled Huawei—regardless of Trump," *Quartz Africa,* May 27, 2019, https://qz.com/africa/1629078/africa-will-stay-loyal-to-chinas-huawei-regardless-of-trump/.
130. OECD, "Export credits: Aircraft specific rules," https://www.oecd.org/trade/topics/export-credits/arrangement-and-sector-understandings/aircraft-specific-rules/.
131. However, its R&D subsidies appear to support less innovative and productive state-favored companies that patent less internationally and engage in more incremental, rather than radical, innovation. https://www.nber.org/papers/w25432.pdf.
132. Doug Brake, "A U.S. National Strategy for 5G and Future Wireless Innovation."
133. John Tammy, "Oren Cass is Advising Marco Rubio on How To Not Be President," *RealClearMarkets,* May 7, 2020, https://www.realclearmarkets.com/articles/2020/05/07/oren_cass_is_advising_marco_rubio_on_how_to_not_be_president_490926.html.