Challenger multinationals in telecommunications: Huawei and ZTE

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Contents

1. Introduction

The telecommunications equipment industry is of high strategic importance. Leading telecommunications equipment suppliers provide their country of origin with equipment for competitive economic and technical development, as well as the capability to influence future technological paths.[1] Additionally, the information and communications technology (ICT) industry is one of the most prominent drivers of globalisation, the evolution of the international division of labour and new models of industrial organisation (Lüthje *et al.* 2013). In recent years Europe's role in the telecommunications equipment industry has been changing rapidly, especially as new competitors from China have entered the market.

The age of the internet, mobile communication, cloud-based services and intelligent/smart manufacturing (known in Germany as Industry 4.0), has amplified the importance of ICT equipment to an unprecedented level. Today, ICT equipment is not only a means of communication, but the backbone of the complex global economy. Furthermore, ICT equipment has become the source of new business models that use it to create new markets, sometimes with explosive growth dynamics and disruptive effects.

Multinational companies from China only recently started to invest in developed markets. As their economic as well as technological strength is constantly increasing it is important to understand how they were able to rise to prominence so quickly and how they are able to influence specific industry developments.

Huawei and ZTE, the leading telecommunications equipment providers from China, are the main focus of this analysis. Both are among the few Chinese companies that have been able to become important global players in the ICT industry. Most significantly Huawei and ZTE are brand-name companies and technology suppliers – roles only a small number of companies from China have yet been able to master. Both companies are formidable examples of how focusing on the development of in-house R&D capabilities can be a long-term strategy for growth. Their specific and highly successful business and innovation model has had a huge impact on the telecommunication industry, driving fundamental restructuring of markets worldwide, as well as of business models.

1. Historically, the development of telecommunication equipment has been a prolific source of innovation and has driven major technological advances (see, for example, Lüthje 1993).

The telecommunications equipment industry has been dominated by companies from Europe and North America from the beginning. Suppliers from other regions were no match for them in neither technology, size nor international importance. This has changed fundamentally since suppliers from China – Huawei and ZTE – entered the industry. Both companies' technological prowess and ability to take part in the standard-setting process for future telecommunications technologies are a showcase for shifts in the centre of gravity in global innovation networks towards countries such as China (He et al. 2015).

This analysis is structured as follows. First we look at changes in fundamental market dynamics since Huawei and ZTE were able to enter the global market for telecom equipment. This is followed by an analysis of both companies in detail, focusing on their customer- and service-oriented business model. Both companies have developed within China's very favourable system of industrial policies focused mainly on technology acquisitions, regulated market access and science and technology programmes, which are the focus of the next part of this paper. However their success was rather an unintended result of these policies – which targeted state-owned enterprises and Sino-foreign joint ventures – coupled with their high adaptability (Pawlicki 2016). The companies' specific innovation focus, which underscores the importance of customer orientation, is described as one of their success factors. The last two parts look at Huawei's and ZTE's R&D investments in Europe, as well as cooperation with regard to European standard-setting processes.

2. Shifts in the markets for telecommunications equipment

The dominance of European and North American equipment suppliers was successfully broken by Huawei and ZTE, who were able to take leading or at least top-five positions in the various markets for wireless and wireline technologies. Both Chinese suppliers differ from incumbent equipment providers through their low-cost products and an innovative business model focusing their product and service innovations on customer needs and requirements.

The United States was the first to start deregulating its telecommunications market in the 1940s. However, due to a very prolonged process full liberalisation was achieved only in the 1990s. In Europe the European Court of Justice and the European Commission opened up markets for telecommunication much more quickly, between the mid-1980s and the late 1990s (Mayer-Schönberger and Strasser 1999).

This has created huge markets for wireline telecommunications equipment while the nascent internet economy has undergone explosive growth. The market structure in Europe in the late 1990s was still determined by the previous system of regulated procurement policies and historically close ties between monopolistic network operators and companies such as Alcatel, Siemens and Ericsson, which were the biggest Europe-based telecommunications equipment manufacturers, accounting for over 20 per cent of EU production, while Nokia accounted for over 10 per cent. On worldwide markets for wireline and wireless network equipment the biggest players – Alcatel, Siemens and Lucent – each had a market share of about 9 per cent (Carr *et al.* 1998).

Europe's strong position in wireless communication dates back to the 1980s when the GSM (Global Standard for Mobile communications) standard was developed by the European Telecommunications Standards Institute (ETSI)[2] and its member companies, within a framework set by the European Community. Participant companies in this process – such as Alcatel, Ericsson, Nokia and Siemens – were able to develop the required technological capabilities before the standard was released and thereby had a huge first-mover advantage (Bekkers *et al.* 2002). As the GSM standard became one of the two dominant wireless standards worldwide, Europe's central role in the

2. ETSI is an independent, not-for-profit, standardisation organisation in the telecommunications industry that comprises both equipment makers and network operators.

development of the subsequent third, current fourth and future fifth mobile communication generations stems from this initial effort.

Table 1 summarises how European telecommunications equipment providers were able to dominate the GSM market in Europe in the initial phase of the sector's development. Already in this period Ericsson was the European technology leader in wireless networks and had a well developed ability to provide system solutions that enabled the networks operator to integrate disparate technology platforms across wireline and wireless networks.

Table 1 **Estimated supplier market share of the 33 largest GSM networks in Europe, December 1996**

Supplier	Market share switching (%)	Market share base stations (%)
Ericsson	48	37
Nokia	14	22
Siemens	21	2
Motorola	1	13
Alcatel	10	10
Lucent	2	4

Source: Bekkers *et al.* 2002.

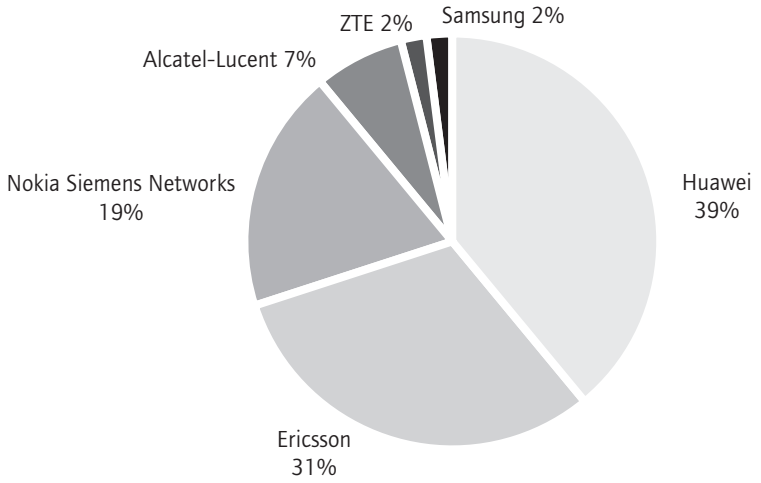
The global markets for wireless telecom equipment have changed considerably since the initial GSM era in the late 1990s. LTE – or Long-Term Evolution, based on the GSM/GPRS and the UMTS/HSPA network technologies – is currently the newest generation of mobile communication standards, and was developed after Huawei's and ZTE's entry into the worldwide markets for wireless technologies. With early in-house technology and product development both companies shed their late-comer status. In 2009 Teliasonera, a Nordic network operator, commenced the operation of the first LTE networks worldwide. Huawei was able to develop one of two test-systems, leading the project in Oslo (Ward 2009).

Contracts secured with network operators indicate the equipment supplier's market success and also reveal their capability to offer leading-edge technology, solutions and services.[3] Figure 1 portrays the fundamental changes in the global markets for leading-edge mobile telecommunications equipment. Asian companies were able to close more than 40 per cent of LTE contracts worldwide by 2013. Although European companies finalized 47 per cent of LTE contracts, Huawei outpaced Ericsson noticeably. With its 39 per cent of LTE contracts Huawei is currently the undisputed market leader in LTE technology.

3. Declared LTE contracts can only be used as an indication to market share based on revenue. However, in the telecom equipment industry initial network equipment purchases are not revenue drivers. Follow-up purchases of equipment and services represent the biggest revenue sources, as network operators are in a relative lock-in situation with their installed base of equipment.

Although ZTE has been able to take only a much smaller market position it is still one of the top-five equipment vendors for LTE.

Figure 1 **Vendors' market share based on declared global LTE contracts, July 2013**



Note: 'Nokia Siemens Networks' is called 'Nokia Networks' since late 2013.
Source: Informa Telecoms & Media Company, Standard Chartered Research.

In the sector for wireline networks Chinese equipment suppliers have had similar market success. By 2012 and 2013, respectively, Huawei became the dominant market leader in both optical network and access equipment markets, while ZTE was able to move into the top five in these markets.[4]

Historically, the third major sector of the telecom equipment industry – Internet Protocol based network products and services – has been dominated by US companies such as Cisco. Currently, the market for service provider routers and switches is controlled by four companies that together account for over 90 per cent of the market: Cisco, Alcatel-Lucent, Huawei and Juniper.[5] While trailing the four market leaders, ZTE has been able to move into fifth position in this sector.

Looking at all three sectors of the telecommunications industry it is evident how the entry of Huawei and ZTE has restructured worldwide equipment

4. See: http://www.businesswire.com/news/home/20120820005311/en/Infonetics-Optical-Network-Spending-15-2Q12-Road; http://www.businesswire.com/news/home/20130220006861/en/Optical-Network-Market-Poised-Growth-2013-Reports; http://www.lightwaveonline.com/articles/2012/08/infonetics-optical-network-systems-revenue-jumps-15-in-2q12.html; http://www.telecomlead.com/telecom-equipment/optical-networking-q2-market-share-huawei-leads-ahead-of-zte-40582-36515
5. See: http://www.channelpartnersonline.com/news/2015/09/cisco-huawei-lead-rising-carrier-routing-switching-market.aspx; http://www.marketwired.com/press-release/network-operators-rate-router-switch-vendors-ihs-survey-cisco-1-third-straight-year-2040950.htm; http://news.ihsmarkit.com/press-release/technology/infonetics-carrier-router-and-switch-market-china-down-north-america-2014

markets. European companies have lost their leading roles in both wireline and mobile sectors, with Ericsson being the only equipment supplier that is competing with Huawei and maintaining its R&D leadership. Additionally, many European suppliers have disappeared as they were either closed down or, more often, acquired by or merged with competitors. Nokia Siemens Networks and Alcatel-Lucent are the major examples of merger strategies used by European and North American companies to fend of rising competition from China. The two organisations do not seem to be able to provide the planned advantages, as the current wave of mergers suggests. In April 2015 Nokia Networks[6] announced the acquisition of Alcatel-Lucent for 15.6 billion euros.

Additionally, the biggest European and US companies have increasingly narrowed their product portfolios. Ericsson and Nokia Networks are major players only in the markets for mobile networks, while Cisco and Juniper focus almost entirely on the IP based networks market. Alcatel-Lucent is the only company that is trying to provide equipment for all three sectors, but is only successful in IP-based and wireline networks (Schwaiger and Gupta 2013). Huawei and ZTE, on the other hand, quite early on diversified into all three sectors, with very broad product and service portfolios; Huawei has been able to develop successfully regarding market share and technology (von den Hoff *et al*. 2008).

Cooperation with European network operators

Long-term partnership relations, technology dependence as well as security considerations were among the most important factors that made the entry into European markets of new vendors such as Huawei and ZTE especially challenging. Additionally, the European market is known for its very high technology and service standards. Both vendors initially focused on telecommunications markets in South America, Middle East and Asia developing overseas experience as well as building up their reputation as trustworthy technology suppliers with considerable cost advantages (see below). Only in 2004 was Huawei able to win its first major contract in Europe with the Dutch mobile operator Telfort, for the development of a third-generation network.

In early 2005, after a rigorous two-year procurement and authentication process, Huawei was selected as one of the strategic suppliers for British Telecom's twenty-first century network programme. Huawei was among industry leaders such as Alcatel, Ciena, Cisco, Ericsson, Fujitsu, Lucent and Siemens, which cooperated on the development and setting of new standards to ensure service interoperability. However, Huawei contributions were limited, providing only access and transmission technology and products to the project. The company was assigned only to lower-value parts of the project.

6. In 2013 Nokia acquired 100 per cent of the shares in Nokia Siemens Networks, thereby also marking Siemens' complete withdrawal from the telecommunications equipment market.

Huawei's alliance with BT was very important for the Chinese equipment vendor as it marked its first supplier arrangement with a first-tier network carrier. This had major implications for Huawei's market reputation and recognition.

By the end of 2007 Huawei was able to secure contracts with all first-tier network operators in Europe. Two years later the company was successful on its main rivals' home turf. In 2009 Telenor decided to upgrade its mobile network and while the companies that originally built the network, Nokia Siemens Networks and Ericsson, both tendered for the project, Huawei was chosen as the main supplier of the new LTE network. In 2014 Vodafone announced that it had awarded Huawei the contract to upgrade its networks in 15 countries in Europe and Africa.

Huawei is currently generating two-thirds of its revenues outside China and Europe is its largest overseas market (Osawa and Zekaria 2014). The company states that it is providing equipment to 37 of the world's 50 biggest operators. Regarding the European market for 4G networks around 50 per cent of the equipment is provided by Huawei (Yoshida 2015).

3. The new incumbents – Huawei and ZTE

Huawei's and ZTE's development and their success on local as well as global markets can be attributed in large part to favourable state policies that were both indirect drivers and facilitators. The development of both companies' strategies based on a customer-oriented business and innovation model have their roots in the Chinese government's development strategy of the 1980s and its industrial policies of the past three decades (Pawlicki 2016).

Based on their corporate strategies and government support Huawei and ZTE have been able to internationalise. Their ability to provide telecommunications equipment adapted to the requirements of developing markets, highly developed customer support and low prices have made both companies very competitive in developing countries, which were the initial focus of their internationalisation. Additionally, the 'go abroad' strategy of the Chinese central government has provided a highly supportive framework since 1999.

Huawei

Huawei was founded by Ren Zhengfei, who is still the company's president,[7] as a sales company for private branch exchanges 1987 in Shenzhen, China. Currently, Huawei is often described as the largest telecommunications equipment supplier worldwide, with revenues of more than USD 46 billion.[8] As the company is not publicly traded financial details are not verifiable, however. Huawei is employee owned, but details on the ownership structure are not publically available. Around 80,000 of the company's 150,000 employees held shares in 2014 (Sevastopulo 2014).

Of Huawei's 150,000 employees about 45 per cent, or 67,500 people, are working in R&D (Huawei 2014). Based on the available data the company's R&D ratio[9] has historically lagged behind its rivals, such as Alcatel-Lucent and Ericsson, by about 5 percentage points. However, the newest reported R&D ratios – 14.2 per cent and 13.2 per cent for 2014 and 2013, respectively –

7. Although he resigned as CEO in 2012 Ren is still the most important figure at Huawei. Since the end of 2012 Huawei has been experimenting with a rotating CEO model, under which three senior management take over the CEO position for six months each.
8. However, the claim is sometimes disputed by experts who point out that Huawei's revenues are not only derived from network equipment operations but also from its mobile phone business.
9. The R&D ratio is defined as the percentage of R&D expenditures in relation to revenue.

suggest that Huawei has been able to catch up with the industry average (Huawei 2014).[10]

Huawei has managed to build up considerable technological prowess and economic strength in components and mobile phones. Huawei's chip design arm, the wholly owned subsidiary HiSilicon, has been the leading domestic chip company in China for many years, while it was able to become the twelfth biggest fabless chip supplier worldwide (PWC 2015). Although the company had been designing and manufacturing mobile phones for several years, it entered the market for smartphones only in 2010. Since then Huawei has become one of the top five mobile phone as well as smartphone vendors worldwide. The company uses its component development capabilities also for its handset business developing mobile processors.

Huawei's newest venture is its enterprise division, which provides IT products and solutions such as storage, switching, routing, cloud computing, broadband access, WLAN, server, videoconferencing, cloud data centres, enterprise networking as well as integrated security and monitoring systems.

ZTE

ZTE (Zhongxing Telecommunications Equipment Corporation) was established in 1985 by Hou Weigui in Shenzhen with investment from China's Ministry of Aerospace.[11] During the 1990s the company evolved to become 'state-owned, privately managed' (*guoyou siying*) (Harwit 2008). Despite its 1997 and 2004 initial public offerings, the biggest shareholder is a holding company owned by a state-owned research institute and a state-owned company (ZTE 2015; Hille 2010).

At the end of 2014 ZTE employed 75,609 people worldwide, of whom more than 27,000 worked in its R&D operations and over 15,000 worked in its manufacturing operations, while customer sales accounted for around 13,000 (18 per cent) (ZTE 2015). The company's R&D ratios are well behind the industry average of around 15 per cent.

ZTE was also a latecomer to the mobile phone and smartphone markets. Although not as successful as Huawei, ZTE was able to become one of the top ten mobile phone and smartphone companies worldwide in 2014.

With their mobile phones business Huawei, as well as ZTE, have taken a completely different development path from their industry competitors.

10. As R&D ratios are based on R&D expenditures, of which wages for technical personnel take up the main share, they can only provide a limited comparison between companies from developed and developing countries. Despite Huawei's internationalisation of its innovation networks, most of its technical personnel are working in R&D centres in China (and also India), where wages are substantially lower than in Europe or North America.

11. Other shareholders included the Shenzhen Municipal Changcheng Industrial Company and the Yunxing Electronic Trading Company.

Ericsson, Nokia and Siemens have had considerable mobile phone businesses, and Nokia enjoyed protracted leadership in the mobile phone markets worldwide. In 2005 Siemens was the first European telecommunications equipment vendor to exit the mobile phone market, followed by Ericsson in 2011, which sold its 50 per cent of shares in the Sony-Ericsson joint venture to Sony. In 2013 Nokia was the last big European telecommunication company to announce its withdrawal from the mobile phone market, selling its business to Microsoft. While the development and design processes of telecommunications equipment and mobile phones differ in complexity, focus, length and investment levels, the ability to establish links between them provides Huawei and ZTE with obvious advantages. Testing procedures, technical interfaces and product stability benefit from a deep understanding of both ends of the wireless telecommunication technology chain. The close relationships that both companies were able to develop as equipment providers with network operators worldwide were advantageous in building up their mobile phone businesses.

Customer service orientation

The Chinese government's industrial policies and market regulations led to segmented rural and urban markets (see below), leaving Huawei, ZTE and the other Chinese telecommunications equipment suppliers with vast rural areas that were offering only slim profit margins, coupled with complex integration problems, such as the varying quality of local power supplies or local government interference. In this environment Huawei and ZTE developed their service-oriented business model. Ahrens (2013) reports how Huawei built up an extensive service network in every Chinese province it was operating in, with over 200 engineers and technicians in counties, towns and small cities. By comparison, Ericsson had only three technicians in the same province. This huge service team allowed Huawei to provide quick, broad and reliable services and was one of its main sales arguments. Additionally, Huawei was able to offer high levels of product customisation that catered for the various idiosyncrasies of a fragile und underdeveloped infrastructure, or simply offered a graphical user interface in Chinese.

Huawei has based both its product development and its market entry strategies on providing products with high stability that fit the customer's application requirements better than competing solutions (Fu and Fu 2012). Their customer-oriented business model helped Huawei and ZTE in their first internationalisation push when entering developing markets in Africa and Russia, where the understanding of impeding factors – technological, political and financial – were fundamental to be able to provide solutions that would cater for local requirements and needs (Cissé 2015; Li 2006). Huawei started its overseas expansion in 1995, while ZTE won its first contracts outside China in the late 1990s. Both companies used a similar strategy first occupying local markets on a loss-leader basis and then growing their profits through maintenance and network upgrades. In 2004 Huawei's overseas sales surpassed its domestic sales.

Huawei's customer orientation drove its early focus on power saving equipment. African network operators required solutions that would allow them to operate in regions without a reliable infrastructure. Huawei's expertise in power saving and wind and solar based networks was later advantageous in cooperating with European network operators as they could both reduce energy costs and advertise these green solutions.

4. China's policies of technology and industrial development – unintended results

In recent decades China's industrial policies directed towards the telecommunications equipment industry have been extensive, integrated and foresighted. However, their initial positive results from a domestic industrial base were only short-term. The Sino-foreign joint ventures supported by the industrial policies had dwindled into insignificance by the late 2000s. The high level of adaptability of Chinese industrial policies made sure that the central government was able to change its bets during the race, favouring firms such as Huawei and ZTE as they rose to success (Pawlicki 2016). The long-term positive effects of China's industrial policies seem to have been unintended as they provided domestic equipment suppliers such as Huawei and ZTE with a set of capabilities that go well beyond technological leadership. Their managerial, organisational and later also technological capabilities allowed both companies to successfully internationalise, supported by government policies, and acquire industry-leading positions.

China's industrial policies resulted in segmented markets that forced new domestic equipment suppliers to move to the rural and low-end markets. Huge state-owned enterprises and Sino-foreign joint ventures focused on the development of manufacturing capabilities as they could access leading-edge technologies through technology transfer cooperation with foreign suppliers. This locked them securely on a development path that could not be successful in an innovation driven industry in the long term. Companies such as Huawei and ZTE initially lacked access to technology transfer systems and science and technology programmes and had to invest heavily in in-house R&D capabilities. It was Huawei's and ZTE's initial decision to focus on developing in-house R&D capabilities that allowed both companies at a later stage to make full use of the development framework set up by governmental policies and regulations (Gao 2011; Pawlicki 2016). Demanding rural markets that shift requirements from technology to organisational capabilities, together with the build up of internal product development capabilities developed into a foundation from which Huawei and ZTE could start their highly successful internationalisation.

In the early 1980s the central government defined the telecommunications infrastructure and industry as strategically important both to provide a foundation for future economic development and as a source of technological strength. However, both the telecommunications industry and local infrastructure were underdeveloped. The central government's strategy was geared towards short-term improvements in telecommunication infrastructure and a long-term evolution of local industry capabilities.

Early on, the central government realised that the size of the Chinese market gave it substantial bargaining power that could be used for technology transfer. Most instruments of China's industrial policy strategy can be summed up under the 'Trading Market for Technology' (TMFT) strategy, resulting especially in Sino-foreign joint-ventures as vehicles of technology transfer. The first Sino-foreign joint ventures with foreign telecom equipment suppliers were established in the mid-1980s.

Favourable taxation and tariff policies supported the TMFT strategy to attract FDI to China. Already in 1991 foreign firms were offered tax concessions, with later laws reducing the tax burden for foreign companies to 11 per cent and 15 per cent in the 1990s (Feng 2010). Import tariffs were also set in such a way that they supported equipment imports and Sino-foreign joint ventures. (Feng 2010). Equipment that was imported based on deals financed by foreign governments and cross-border organisations was exempt from any tariffs. After China's accession to the WTO the country ended all special-treatment tariff policies in 2001.

In the mid-1980s investment in telecommunications equipment was decentralised to the provincial level. This step was especially important for the big coastal cities that needed to provide modern communications infrastructure for foreign investors (Hong *et al.* 2012). These new investment projects led to an increase in foreign loans, usually conditional on buying equipment from creditor countries. In addition, Chinese companies were not able to provide the necessary modern equipment. The central government stopped accepting foreign loans in 1995 and established a domestic system of financial assistance. While this decentralisation led to a segmentation of the Chinese market that increased the divide between rural and urban areas the Ministry for the Information Industry released a briefing that concluded that wireless network operators should buy local equipment wherever possible by the late 1990s (Fan 2011; Harwit 2008).

A similar 'buy local' strategy was used in the wireless sector. In 2006 China Mobile and China Unicom, the biggest Chinese network operators and both state-owned enterprises, unified their purchasing policies with regard to GSM equipment. While provincial operators were still able to choose their supplier independently, they had to follow centrally set prices (Fan 2011). Furthermore, China Mobile's new procurement policy openly favoured domestic suppliers (Hong *et al.* 2012: 919). This regulation had an almost instantaneous effect. In 2007 Huawei and ZTE had a 13 per cent share in the Chinese GSM market, while Ericsson had 42 per cent; in 2008 the two companies were able to take 37 per cent of the Chinese GSM market (Hong *et al.* 2012).

Chinese innovation policies aimed at developing national champions drove the development of a Chinese third generation wireless technology called TD-SDCMA. China's central government provided extensive support for its TD-SCDMA project through funds, regulations and organisational help, while Datang, Huawei, China Mobile, China Telecom and China Unicom were the main Chinese companies that cooperated on this project. The project was

highly complex and only partially successful (Tsai and Wan 2011; Hou 2011) as the standard did not become viable outside China. However, Chinese telecommunications companies were able to build up technological expertise and standardisation process experience and used these learning processes for their R&D on the fourth and fifth generation wireless technology.

TD-LTE, the 4G direct successor of TD-SCDMA seems to be much more of a success, having been chosen as one of the two global 4G standards by the ITU. Huawei and ZTE are investing substantially in TD-LTE technology and together with other firms – such as China Mobile, Datang Telecom, Nokia Solutions and Networks, Qualcomm, Samsung, and ST-Ericsson – are part of an international coalition that is developing the standard further.

Huawei's and ZTE's initial expansion to developing markets coincided with the Chinese government's push for internationalisation (Di Minin *et al.* 2012; Pawlicki 2016). In 2000 the tenth five-year plan and associated tenth five-year Plan on Inward and Outward FDI, directly explained the 'go global' strategy as a way to encourage OFDI in areas in which competitive advantages exist and to further develop international economic and technological cooperation. The 'go global' policy is an extension of the overall policy framework of Chinese economic development with two main objectives: to facilitate OFDI in order to nurture the international competitiveness of Chinese firms and to use OFDI for the country's general economic development (Sauvant and Chen 2014). Favourable credit lines for overseas investments were an important instrument of the 'go global' strategy.

5. Innovation the Chinese way?

While incumbent Chinese telecommunications equipment suppliers such as Eastcom focused on manufacturing and on joint ventures for technology acquisition and catch-up, Huawei and ZTE embarked on a more long-term development. From the outset both companies' central strategies was the development of in-house innovation capabilities, through investments in R&D personnel and own product development (Gao 2011). This strategy of in-house innovation was aimed at the development of core technologies that would enable innovation-driven differentiation while keeping the low-cost advantage and developing complementary capabilities, such as professional management and customer orientation, coupled with very broad and fast customer service.

The telecommunications industry was long dominated by technology-led innovations. In industry lingo, 'over-engineering' of new equipment often occurred, where the technological and technical possibilities were the driving factor in development while questions of application were asked only later on. Over-engineering is partly based in the technological and managerial capabilities of providers and customers. Incumbent network operators with their workforce of highly experienced engineers, operators and maintenance staff were able to put the many functions provided to use. This changed with the emergence of less mature markets and new market entrants. Here, initially, the technical personnel did not have the necessary experience and customers did not seek the abundance of functions and services. The major focus was to be able to provide a stable and cost-effective telecommunications infrastructure in a short time.

Box 1 **SingleRAN**

Huawei's SingleRAN (radio access network) enables mobile operators to seamlessly switch from 2G to 3G or to use both technologies simultaneously. This allows for cost savings through lower numbers of base stations as well as lower energy consumption. SingleRAN is based on the software-defined-radio technology, which enables simpler technology evolution as new standards can be implemented on the software layer and do not need new hardware.

Huawei's and ZTE's customer-oriented R&D model was driven by their late-comer role; neither their technological experience nor their financial resources were sufficient to pursue a technology-led innovation model. As both companies commenced their globalisation focusing on developing countries

before moving towards more mature markets their capability to provide customer-oriented innovations proved very useful.

While the model of technology-oriented innovation is not coming to an end, the major changes in the markets for both wireline and wireless telecommunications for network operators and equipment suppliers are facilitating changes in requirements formulated with regard to new equipment also in mature markets. Huawei's numerous innovation centres, in which the company cooperates with its main customers, provide the necessary integration of customer needs and requirements directly into the R&D process. A good case in point is the SingleRAN technology that has been developed in cooperation with Vodafone at the Mobile Innovation Centre in Madrid and has become an industry standard since its introduction in 2008.

In recent years Huawei has announced that it will shift its R&D focus towards technology-driven innovation that will still incorporate future customer needs (BMI Knowledge 2014). While the company wants to retain its high customer orientation the slight refocusing is a sign of the company's increasing confidence in its technological capabilities as well its ability to define future technology trends.

Patents

In 2008 Huawei was still lagging behind its main competitors Ericsson, NSN, Motorola and Cisco regarding its base of patents. However, the company's huge investments in R&D and its focus on further developing in-house R&D capabilities allowed it to catch up quite quickly (von den Hoff *et al*. 2008). Huawei started to increase patent applications under the Patent Cooperation Treaty (PCT) and at the European Patents Office (EPO) already in 2006, becoming top PCT applicant in 2009. ZTE's application drive started only in 2009, but in 2011 the company was the top PCT applicant. In 2011 both Huawei and ZTE were among the top ten companies – alongside Panasonic, Sharp, Bosch and Ericsson – in international PCT applications (Table 2).

Table 2 **Published PCT international applications by top ten applicants in 2011**

Ranking	Applicant	Country of origin	PCT application published in 2011
1	ZTE Corp.	China	2826
2	Panasonic Corp.	Japan	2463
3	Huawei Technologies	China	1831
4	Sharp Kabushiki Kaisha	Japan	1755
5	Robert Bosch Vorp.	Germany	1518
6	Qualcomm Inc.	USA	1494
7	Toyota Jidosha Kabushiki Kaisha	Japan	1417
8	LG Electronics Inc.	South Korea	1336
9	Koninklijke Philips Electronics N.V.	The Netherlands	1148
10	Telefonaktiebolaget LM Ericsson	Sweden	1116

Note: Huawei is now also a major applicant for EPO patents; however, both Huawei and ZTE are absent from the top 50 application list at the US Patent Office. Source: Kang 2014.

6. European focus of global innovation networks

Since it established its European presence by opening a R&D centre in Kista, Sweden in 2000 Huawei has built up a substantial Europe-based innovation network with 18 R&D centres in 10 European countries, employing around 1,200 researchers (Table 3). Additionally, Huawei has 19 joint innovation centres in Europe where the company is cooperating directly with its main customers, such as Vodafone and British Telecom, on technology sharing and joint application development. Furthermore, Huawei operates two regional technical assistance centres, 10 training centres and five local network operation centres in Europe. Its two regional headquarters, Warsaw and Düsseldorf, 41 sales branches, two logistic centres and 46 country-level spare parts centres are focused on sales and distribution responsibilities for this region. Overall Huawei employed 9,900 people in Europe in 2014. From a technology perspective Huawei's 18 European R&D units cover all three carrier segments – wireless, wireline and optical – as well as both network infrastructure and mobile phones.

Huawei has increased investments in its European R&D since 2007 by 27 per cent a year, reaching 137 million euros in 2011. The company's European investments amounted to around 3.8 per cent of its worldwide R&D investments in 2011 (Huawei 2013).

Currently Huawei operates more R&D units in Europe than in any other region of the world. However, most of the company's engineers are employed in China and India, where Huawei operates R&D campuses of considerable size. At its Shenzhen headquarter and main R&D campus 40,000 people are working, while its only Indian R&D centre in Bangalore has been recently expanded to house 5,000 engineers. With around 1,200 employees in total the 18 European R&D centres are very small – ranging from 10 employees in Paris to 350 in Kista and 500 in Moscow. Albeit not very precisely, the size of R&D units can be used as a first indicator of their role within global innovation networks. The small Huawei European R&D centres suggest that the company is conducting projects that are research oriented, working on leading technologies, developing and acquiring new knowledge. R&D units of this size are not able to conduct implementation or productisation projects as this requires more engineering manpower, as well as auxiliary functions such as sales and marketing, customer relations or manufacturing planning, which are necessary to move through development to manufacturing and to the market.

A very good indication of Huawei's R&D focus in Europe are its operations in Kista, with their strong focus on research. Engineers from this centre only

Table 3 **Huawei's R&D locations worldwide**

Region	Country	Location	Focus
Asia	China	Shenzhen	HQ, carrier network, service platform, manufacturing, administration
		Beijing	Packet Core Network, GW, Terminals
		Chengdu	Carrier network and enterprise businesses
		Dongguan	Manufacturing
		Hangzhou	Network carrier, enterprise business
		Langfang	Sales and service
		Nanjing	Carrier network, BOSS, 3G services
		Shanghai	RAN, terminal, ASIC, chipset
		Xi'an	Carrier network and enterprise businesses
		Wuhan	Carrier network and consumer businesses
	India	Bangalore	Software technology/platform
Europe (about 1200 engineers)	Belgium	Brussels	Carrier software, application software architecture
		Leuven	5G
	Denmark	Copenhagen	NA
	Finland	Helsinki	Software for mobile devices
	France	Paris	Standards
		Sophia-Antipolis	Chipsets and embedded technologies, smartphone cameras, build up of expertise for image signal processors
	Germany	Bonn	Wireline network
		Düsseldorf	NA
		Munich	Antenna, future network technologies, hardware and engineering, media technology, terrabits optical systems, Optical Transport, Access Network, Core Network, Application & Software and IP; Future Carrier Networks, key technology components for 5G
		Nuremberg	(Renewable) Energy Technology, solar inverter solutions
	Ireland	Dublin / Cork	IT/software, next generation Customer Experience Management Product
	Italy	Milan	Microwave, optoelectronics
	The Netherlands		NA
	Russia	Moscow	Algorithm, RF
	Sweden	Gothenburg	Radio Base Systems
		Lund	Smartphone
		Kista / Stockholm	Base Station architecture and system design, radio technologies, RAN algorithm
	UK	Banbury	Cyber security evaluation
		Bristol	Processor core development
		Ipswich	Integrated photonics / optoelectrronics
Americas	USA	Bridgewater, NJ	Wireless
		Dallas, TX	ASIC technologies, CDMA algorithm
		Plano, TX	HQ (regional)
		San Diego, CA	Terminal technologies, chipsets
		Santa Clara, CA	NA

Source: company information, author's research.

participate in the first steps of development projects, providing concepts and initial prototypes, while productisation takes place in China.

All but one of its European R&D centres are greenfield investments. Huawei established its R&D centre in Ipswich, focusing on advanced integrated photonics and optoelectronics technologies, by acquiring a world-leading photonics research laboratory – the Centre for Integrated Photonics – from the East of England Development Agency, in 2012.

Three of Huawei's 18 R&D centres in Europe serve very special goals. In Nuremberg, Germany engineers are looking into technologies in the field of renewable energy, developing products for its solar inverters. As solutions provider Huawei is offering power supplies for its telecommunications equipment as well as data centre solutions. In 2015 the company opened its first worldwide aesthetics and design centre in Paris. Huawei's Banbury operations were opened in 2010 in response to allegations about the company's role in cyber security issues and the related mistrust that had a negative impact on its ability to participate in rollouts of several national broadband networks. Under the oversight of the Government Communications Headquarters (GCHQ), a British state intelligence and communication organisation, engineers at the Cyber Security Evaluation Centre are inspecting Huawei's equipment, both hardware and software, for vulnerabilities.

During its more than 15 years of development Huawei's European innovation network has experienced substantial upgrading. The R&D centres in Munich and in Milan are two cases in point. Only four years after opening its R&D centre in Munich, Huawei started to upgrade this location to become the European Research Centre and Central Research Institute in 2012. This development led to an expansion in research focus that currently encompasses hardware and software research for wireline, wireless and optical networks, as well as applications. One key focus of research projects in Munich is the future 5G mobile telecommunications standard. The European Research Centre in Munich plays a very important role in Huawei's long-term research plans as it is performing fundamental and applied research. Simultaneously, Munich's role in the control structure of the innovation network changed, as functions were added for leading and managing Huawei's European research operations, as well as some of its innovation centres. In May 2015 Huawei announced the opening of a new R&D centre in Leuven, Belgium as the European Research Institute. The institute will focus its research on the 5G wireless standard while taking over Munich's role managing Huawei's European R&D operations. It is still not clear how this development will affect Munich's role in Huawei's global innovation network.

Milan was established in 2008 as a highly specialised R&D centre focusing on microwave and optoelectronics. In 2011 the operations were upgraded to become the Microwave Competence Centre, by locating here not only the global R&D activities in this field, but also service, marketing and sales support. The integration of sales and marketing and services is an important step in the upgrading of R&D centres as these functions are enabling higher ownership of

R&D projects through direct customer relations and the resulting knowledge flows (Pawlicki 2014). The Milan competence centre was also Huawei's first competence centre outside China, indicating how important Milan and Europe are within the company's innovation network.

From the data currently available on the development of such Huawei locations as those in Kista, Milan, Munich and Leuven some first tentative conclusions are possible. It appears that the company's European innovation network is moving to a more mature role regarding both R&D and management. Increasingly, an intermediate control level has been established with regional management structures, giving European locations more room for own oversight. While initially managerial positions in Europe were staffed with Chinese managers, currently most country vice presidents are from Europe while country CEOs are still from China. Regarding R&D it appears that European locations are increasingly being enabled to drive research projects within Huawei's centrally defined research and product development guidelines/plans, while increasing their ownership of these projects. Milan's competence centre is a case in point. However, as Europe lacks the manufacturing operations the question remains how far innovation capabilities can be developed, as one of the most crucial links is missing locally (Ernst 2005; Lüthje and Pawlicki 2009).

Huawei's decision to establish R&D operations in Europe was driven by knowledge-seeking strategies, as well as the need to facilitate market entry. With its newest investments in Sophia-Antipolis, Bristol and Leuven Huawei is moving its knowledge-seeking strategies towards the component level and is trying to strengthen its proximity to standardisation institutions. Chipset and processor design are an important part of developing both equipment as well as terminal products. Bristol and Sophia-Antipolis are major European science and technology locations specialising in electronics and housing large numbers of world-class semiconductor companies. Additionally, several universities have outposts in Sophia-Antipolis; the headquarters of the European Telecommunications Standards Institute is also located there.

Compared with Huawei, ZTE's R&D operations in Europe are minuscule. Of its 18 worldwide R&D centres only two are in Europe, with some additional operations in this region (Table 4). Similar to Huawei, ZTE's first R&D-related investment in Europe established its research operations in Kista, where the company has been developing its mobile networks core technology. In France, Germany and the United Kingdom ZTE is focusing on technical support, as well as cooperating on development projects with its main European customers. In 2014 ZTE opened an R&D centre in Braga, Portugal with the help of Minho University, the DST group and InvestBraga. The centre is aimed at developing and testing new services and applications in the telecommunications sector.

Table 4 **ZTE's R&D/innovation locations worldwide**

Region	Country	Location	Focus
Asia	China	Shenzhen	NA
		Beijing	NA
		Langfang	Optical transmission and data communication
		Nanjing	Network Division, the Data Division as well as the Central Academy and ZTESoft; mobile networks, data networks, fixed networks, NGN-oriented Softswitch products, telecom value-added services, operating support systems and network core equipment
		Shanghai	Smartphone
		Xi'an	NA
	India	Bangalore	
Europe	France	Poitiers	
	Germany	Düsseldorf	
	Portugal	Braga	
	Sweden	Kista / Stockholm	3G – baseband and algorithm
	UK		
North America	USA	Dallas, TX	4G technology, Mobile Device technology, and WiMAX, CDMA and LTE related technologies
	Canada	Ottawa	Smartphone, hardware and IC design

Source: company information, author's research.

Cooperation for standard-setting in Europe

In its brochure on the company's European R&D activities Huawei discusses the EU eighth framework programme Horizon 2020 extensively and links it with its own '2020' vision, while also formulating recommendations to the European Union (Huawei 2013). Regarding the ambitious ICT priorities highlighted by the Horizon 2020 programme Huawei advocates focusing on a number of areas, including 5G mobile networks, network services and functions, 3D audio and video as well as augmented reality, and a cross-domain middleware for the Internet of Things.

Although Huawei was a latecomer for the development of the 3G mobile standard it was able to develop technological capabilities that allowed the company to catch up with its competitors for the 4G, or LTE, standard. However, the company was not able to play a major role in the process of defining and developing the 4G standard. For the fifth technology generation Huawei's goal is to actively co-define standards and technologies and contribute to ecosystem development, allowing the company to develop a first-mover advantage. To achieve this the company started to invest in 5G R&D already in 2009.

The initial process of defining the next mobile standard, 5G, began around 2012/13, when among others the European Commission committed 50 million euros for research on 5G wireless technology. Huawei has been an active member of the EU project METIS (*Mobile and wireless communications*

Enablers for the Twenty-twenty Information Society) from the start.[12] The implementation of METIS involves overall eight work packages. Huawei's European Research Centre in Munich is leading the research on the work package focusing on the new radio link concepts and design that the 5G technology requires (METIS 2013). The European Research Centre is also a key contributor to the 5G Infrastructure Public Private Partnership defined by the European Commission.

Huawei's strategy is to closely work with policymakers, as well as regulatory standards and research institutions across Europe to push forward the research and standardisation agenda on 5G technology, as well as secure its involvement. Through various workshops, conferences, talks and reports the company is actively lobbying both publicly and in relation to specialist technical and industry communities. Huawei is active in the following EU projects: ARAGORN, FARAMIR, BONE, DICONET, CHRON, CONSERN, TREND, ULOOP, FI PPP – SmartAgriFood (SAF).

In 2015 the 5G innovation centre at the University of Surrey was established, with the additional investment of major telecommunication and electronics companies, such as Fujitsu, Vodafone, Samsung and Huawei. Huawei announced the investment of GBP 5 million for a test bed to be set up at the future 5G innovation centre.

Announcing the launch of the European Research Institute in Leuven, Belgium is Huawei's most recent step to consolidate and further strengthen its cooperation with the European telecom industry and academia, as well as with policymakers and standardisation institutions in Europe. One of the main focuses of the future institute will be supporting Huawei's various 5G projects under way in Europe.

12. The METIS consortium comprises equipment vendors, telecommunication operators, car companies and academic organisations.

Conclusion

Huawei and ZTE provide insights into how Chinese companies have been able to become leading technology suppliers in highly competitive and technologically demanding industries. This should inform trade unions, policymakers and companies in Europe about China's changing role in the global economy, and also about how to recognise possible threats from Chinese companies. Chinese companies increasingly are able to catch up with their competitors from Europe and worldwide. Investing in Europe such companies are interested in technical personnel and their expertise. With this they are becoming a stabilising element of the R&D capabilities in Europe, while integrating them further in the wider reaching global innovation networks of the ICT industry. Questions of labour conditions and labour relations need to be followed up in depth as this integration is driven by non-European investors.

Europe still has an important role in the telecommunications industry, especially in mobile networks. The newcomers Huawei and ZTE have increased competition and have left some European companies in a dire economic situation. However, their investments in Europe and their interest in cooperation, especially in the development of mobile communication standards, seems likely to solidify Europe's role as a research and standard-setting location. But there are no guarantees.

The success of both companies is interesting with regard to business strategies as well as industrial policies. With their horizontally and vertically broad business strategies, which encompass all three major sectors of telecommunications equipment, as well as integrating components and mobile phones Huawei and ZTE have countered the widely held believe that technology companies need to focus on key markets and key competences. While they firmly rely on the industry standard of vertical specialisation (Lüthje *et al.* 2013), outsourcing major parts of manufacturing, they have established a very broad set of technical, organisational and managerial capabilities that seem to be increasingly important. As network operators are facing rising competition and lower profit margins, Network Managed Services are increasingly becoming an important business model, in which equipment vendors are taking full responsibility for networks. Starting with planning, designing, building and operating a network for their customers, equipment companies also provide field maintenance as well as capacity and spare parts management. Additionally, the integration of wireless, wireline and IP-based networks is moving on. The Chinese equipment suppliers seem to be better prepared for these future markets than their Western competitors.

The case of Huawei and ZTE indicates the importance of integrated industrial policies, especially those that are extensive, integrated, foresighted and, in particular, adaptable. While neither company was in the initial technology acquisition focus of China's industrial policy they profited in various ways from their existence. Most important, however, was the ability of policymakers to adapt quickly to the results of their policies, namely to the demise of the initially supported equipment companies and the rise of the new contenders. This should be a wake-up call for all policy stakeholders in the EU. First, as it shows that very direct industrial policies do work, even though sometimes they produce unintended results. Second, in an increasingly globalised economy China is upping the ante of politico-economic development, thereby changing the conditions for competition. Finally, industrial policies make it possible not only to drive technological and economic development, but also the propagation of 'decent work', in other words, labour conditions and labour relations that are beneficial for broader social participation by equipping future policy instruments with clauses for social conditionality.

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