

Marcus, J. Scott

Conference Paper

Evolution of mobile infrastructure equipment unit prices in light of a constrained choice of suppliers

ITS 33rd European Conference 2025: "Digital innovation and transformation in uncertain times", Edinburgh, UK, 29th June – 1st July 2025

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Marcus, J. Scott (2025) : Evolution of mobile infrastructure equipment unit prices in light of a constrained choice of suppliers, ITS 33rd European Conference 2025: "Digital innovation and transformation in uncertain times", Edinburgh, UK, 29th June – 1st July 2025, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/331292>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Evolution of mobile infrastructure equipment unit prices in light of a constrained choice of suppliers

The opinions expressed are solely those of the author.

Prof. J. Scott Marcus
Bonn, Germany
scott@scottmarcus.com



Contents

1.	Introduction	4
1.1	Methodology	4
1.2	A word about the cost of migrating away from the use of mobile infrastructure equipment manufactured in China.....	5
1.3	Caveats and limitations	5
1.4	Structure of this report.....	6
2.	Restrictions place on Chinese manufacturers in various jurisdictions.....	7
2.1	United States	7
2.2	European Union.....	8
2.3	United Kingdom.....	10
3.	The overall evolution of infrastructure equipment shipments and unit prices worldwide.....	11
3.1	Shipments of 4G and 5G versus earlier generations	12
3.2	Market shares worldwide.....	13
3.3	Unit price trend over time.....	14
4.	The overall evolution of infrastructure equipment shipments and unit prices by region and by supplier	15
4.1	Shipments of 5G macro BTS by region	15
4.2	Revenue shares by region for key vendors	18
4.3	Revenue shares by vendor in key regions	19
4.4	Average selling price (ASP) by region and supplier	19
5.	Transition issues where restrictions have been introduced	23
5.1	The need for parallel operation during transition.....	23
5.2	Impact on Operational Support Systems and Business Support Systems.....	23
6.	Impact of total mobile network cost on societal welfare	24
6.1	Mobile infrastructure costs as a fraction of total costs.....	24
6.2	Impact on consumer prices and societal welfare.....	28



Working Paper

7.	Summary and concluding observations	29
7.1	Assumptions and caveats	30
7.2	Implications for public policy.....	30
8.	References.....	32

Figures

Figure 1.	Global mobile network data traffic and year-on-year growth (EB per month).	11
Figure 2.	Mobile subscriptions by technology (billion).	13
Figure 3.	5G NR Base Stations deployed, by region (June 2021 - June 2024).....	16
Figure 4.	5G NR Base Stations shipped, by region (2022 - 2024).....	17
Figure 5.	5G NR RAN revenue share by region (all vendors) (combined 2018 - 2023).....	18
Figure 6.	5G NR macro BTS revenue and 5G NR macro BTS deployed (cumulative 2018 – 2023) (global share in %).....	20
Figure 7.	5G NR macro BTS Average Selling Price (ASP) for China, the USA, and the rest of the world (cumulative 2018 – 2023) relative to the worldwide average over the same period.	21
Figure 8.	Total MNO OPEX worldwide (\$ mn) (1Q2019 - 4Q2020).....	25
Figure 9.	Total MNO CAPEX worldwide (\$ mn) (1Q2019 - 4Q2020).....	25
Figure 10.	Breakdown of MNO OPEX (2019 and 2021).	26
Figure 11.	Total MNO CAPEX worldwide excluding spectrum (2016 - 2025).	27

Tables

Table 1.	Estimated number of 5G NR macro BTS deployed (2020 - 2024).	15
Table 2.	The shifting trend in macro BTS (all technologies) ASP across the different suppliers (2012 - 2023).	22



1. Introduction

This study seeks to quantify how a total exclusion of mobile infrastructure equipment made by Chinese manufacturers (Huawei and ZTE) has been on wholesale equipment prices, and by implication, how implementation of a similar exclusion in Europe or elsewhere might influence wholesale mobile infrastructure equipment prices.

In that context, this paper seeks to do something that to the best of our knowledge has never been done – to quantitatively estimate key elements of the economic impact that a complete exclusion of Chinese mobile infrastructure equipment could be expected to have, in comparison with the current status quo.

Our objective in this study is to quantify the impact of a full exclusion in order to help policymakers to make informed policy decisions in this very complex space. We do not seek to provide comprehensive guidance on how to proceed – that involves complex factors that are outside the scope of the current study.

1.1 Methodology

A key question is the degree to which exclusion of Chinese mobile infrastructure providers would change (increase) the cost of network deployment on the part of network operators. This is not an easy question to answer. One cannot simply ask the equipment suppliers or the network operators, first because the data will tend to be highly commercially sensitive, and second because one would likely get self-serving answers even if they were willing to provide them.

Individual prices paid by individual network operators to individual suppliers will tend to be highly sensitive, but the total manufacturing revenue of equipment provider firms often are known or knowable, not least because investors need to know.

Revenue is just price times quantity, $p * q$. If we know the volume of equipment shipped (which is q), and the associated total manufacturing revenue, then we know the *Average Selling Price (ASP)* (which is p). This is in many respects better than knowing the unit price that a firm nominally charges, because any special discounts or other provisions are automatically reflected in the ASP measured in this way.

The total manufacturing revenue of the supplier firms is available in a commercial dataset provided by a well-respected market research firm, Dell'Oro. The quantity data is a trickier question, because that revenue is associated with a mix of products. A large portion, however, is associated with the large (macro) *base stations* that constitute a major component – for those, we have data on both p and q at global level (not at regional), and can compute the ASP directly.

Our expectation, which has been born out by the data, was that the full exclusion of Chinese vendors (as in the USA) would tend to increase deployment costs for mobile networks in two different ways:

- The effective disappearance of two major competitors in an essentially oligopolistic market can be expected to enable the remaining market players (mainly Ericsson, Nokia, and Samsung) to exercise their increased market power by raising prices.



- The unfortunate reality that the suppliers that are excluded from the market are the most cost-effective suppliers likewise implies an increase in the average unit price paid in countries or regions that have a full exclusion on Chinese gear.

The first of these two effects could be expected to work differently in different countries or regions because there are countries – not just China itself, but also many others – where few restrictions on Chinese gear are in effect, or none at all. The unit prices that Ericsson, Nokia and Samsung charge in those countries and regions can be expected to be substantially different from the unit prices in regions such as the United States where the exclusion is total, because Ericsson and Nokia face stiff competition in those countries.

The bulk of this study is concerned with estimating the combined magnitude of these two effects. It appears to be much larger than we would have expected.

1.2 A word about the cost of migrating away from the use of mobile infrastructure equipment manufactured in China

Where Chinese equipment has already been deployed, additional costs can be expected to migrate away from it.

First, the software used to operate the network, and to perform customer billing, is likely to require substantial enhancement. For a large network operator like Deutsche Telekom, this entails significant cost, as we explain in Section 5.2. The relative impact might be even greater on smaller network operators inasmuch as the costs are similar, but they have to fund out of a smaller volume of total revenue.

A second factor in these non-greenfield situations is, as we now know from the US *Rip and Replace* program, there are significant costs associated with parallel operation of Chinese and replacement equipment during a transition period that might well extend over a period of several years. The equipment may be nominally interoperable at the air interface level, but less so in terms of management interfaces. (Kang, 2023)

For these transition costs, we report in Chapter 5 on a few facts that appear in the press and the literature, but we have not attempted a detailed quantification.

1.3 Caveats and limitations

Our Dell'Oro dataset provides most of the data that we would ideally want, but not all.

We have good data on total worldwide shipments of base stations by quarter and by year as of July 2024 going back many years (and also annual forecasts for the coming five years), and on corresponding revenues by vendor. We have concentrated on 5G macro base stations (BTS) because those are more of a less commoditised product, and because a fair bit of data is available.



By region, we have good data on revenues, but unfortunately not on shipments by region or country. Ideally, we would have liked to show that ASP from non-Chinese vendors went up (probably with a lag) when restrictions were introduced in for instance the United States, but in the absence of shipment volume data, we do not have a straightforward way to demonstrate this. We have attempted, however, to make some rough estimates. The worldwide ASP data definitely shows movements over time in response to restrictions, but it is difficult to reliably tease out the effects from those because worldwide figures are a composite mix of countries that imposed restrictions and countries that did not choose to do so.

Under our license conditions with the vendor of the data, we cannot show their data in this report, even though many of our calculations are based on their data. This same data is however licensed by many network operators and financial institutions, so there are a great many experts who would have no difficulty checking our work if they wish to.

Our main source of geographically differentiated data on shipments reflects estimates in a series of reports by the *5G Observatory*, the most recent of which is (5G Observatory, 2024), of the number of 5G macro BTS deployed. One would normally expect these data to be reliable, inasmuch as they are published by the European Commission; however, it is quite possible that the *5G Observatory* estimates of 5G macro BTS deployed in the USA are too low. If so, this might explain a portion (but not all) of the seemingly high unit prices in the US, since many of our computations reflect total revenue divided by quantity. There is however good reason to believe that any errors cannot be too large – otherwise, the total volume of 5G NR macro BTS shipped worldwide (known from other sources) would not be possible.

1.4 Structure of this report

Following this introductory chapter, Chapter 2 provides a summary of the restrictions that have been introduced, or that are in the process of being introduced, in the United States, the EU, and the UK. Chapter 3 provides a quick summary of broad trends at a global level. The chapter also provides shipment data for selected countries and regions based on data from the 5G Observatory. Chapter 4 provides analysis at a regional level, and concludes with a comparison of ASP of 5G macro base stations (BTS) in the USA, China, and worldwide. Chapter 5 touches on transition issues that are noted above – the need to upgrade or replace Operational Support Software, the complexity of parallel operation of equipment from two different vendors. Chapter 6 considers how the differences in ASP of macro base stations (BTS) impact overall OPEX, CAPEX, and consumer prices. Finally, Chapter 7 provides overall conclusions.



2. Restrictions place on Chinese manufacturers in various jurisdictions

This chapter provides a summary of some of the key restrictions that have been imposed, or are in the process of being imposed, on Huawei and ZTE equipment in various developed countries. Large portions of this section are based on the excellent analysis conducted for EBRD by Cullen International in parallel with this report.

There are several reasons for providing a summary of restrictions in this report. Notably, doing so provides context as to *when* restrictions were introduced. It also becomes evident that the restrictions introduced in different countries are very different in their severity. These together provide important context as regards how restrictions might have impacted the market (and thus prices) for mobile equipment in the countries concerned.

In an ideal world, we would have mapped the time at which sanctions were introduced against the movements in the price of base stations; in practice, the data available to us are good, but they are not sufficiently granular to make this possible. Also, since neither Huawei or ZTE ever sold any 5G gear whatsoever into North America – sanctions hit just as the first 5G gear was ready to ship – there is no measurable shock to enable econometrics.

2.1 United States

US concerns about Huawei equipment go back for decades, including unsubstantiated claims that the equipment was being used for surveillance. Be that as it may, concerns over the use of Chinese infrastructure equipment have to be taken seriously in order to minimise risk in the event of a possible confrontation between the United States and China.

In the USA, major MNOs AT&T, Verizon, and Sprint were never allowed to buy Huawei equipment. An outright ban on the use by US federal agencies reporting to the President of equipment produced by Huawei, ZTE, or three Chinese providers of video surveillance equipment became effective in 2019. Smaller MNOs were still allowed to purchase Huawei or ZTE.

Laws followed. The *Secure and Trusted Communications and Networks Act of 2019 (STCNA)* and the *Secure Equipment Act of 2021 (SEA)* empowered the US FCC to impose restrictions on telecommunications equipment and services. In February 2023, the FCC applied these powers to equipment manufactured by Huawei and ZTE, including handsets. This created a hard ban: federal funds could not be used to purchase or support covered equipment, and existing covered equipment already purchased with federal funds had to be permanently removed and replaced.

The bans were fully effective in blocking new purchases. The Dell’Oro data that we use elsewhere in this report show that neither Huawei nor ZTE had any manufacturing revenue whatsoever for 5G infrastructure equipment sales into North America; however, removal of equipment already installed proved to be challenging and time-consuming.



Working Paper

Under the STCNA, the small, rural mobile network operators (MNOs) (of which the USA has a great many, contrary to what you might think) were required to de-install equipment by dates ranging from 29 May 2024 to 4 February 2025. Even though \$1.9 billion was allocated to reimburse them for their costs, this will not suffice – the FCC estimates the real cost to be \$4.98 billion, representing a shortfall of some \$3.0 billion! Many of the recipients are small rural MNOs that could be driven out of business by complying with the law if they are not reimbursed. The FCC has granted a huge number of individual extensions, but they will not suffice. (Rosenworcel, 2024)

It is worth noting that the total combined value of mobile RAN equipment of all technologies sold by Huawei and ZTE into North America (thus not only the USA but also Canada, Mexico and more) is less than \$1.5 billion according to Dell'Oro. That the expected cost of replacing the equipment is at least three times as great as the initial purchase cost is sobering. Perhaps this reflects the increase in price after Chinese firms were prohibited from selling in North America (see Section 4.4); perhaps it also reflects other transition costs, such as the cost of re-working operational support software (see Section 5.2).

The US Department of Commerce (DOC) also added Huawei to its *Consolidated Screening List (CSL)*, thereby preventing US firms from providing Huawei with certain kinds of US technology without prior DOC approval. The restriction on the sale of chips produced using US technology (including chips produced in third countries) had a substantial impact on Huawei, but this is not particularly material to the current report.

2.2 European Union

In the European Union, the key policies are established by the Cybersecurity Toolkit (NIS Cooperation Group, 2020). The Toolkit is a sophisticated little document that appears to reflect careful analysis and risk assessment by capable experts.

The trade press, together with the former Commissioner previously responsible for DG CNECT, have often over-simplified the conclusions as if they called for a rip-and-replace program similar to that of the United States. In fact, the Toolkit puts forward a much more nuanced and sophisticated approach, calling for actions by the Member States and the Commission, as well as for an extended lease on life for the NIS Cooperation Group so as to enable it to continue to monitor progress.

The recommendations to the Member States are as follows:

All Member States should ensure that they have measures in place (including powers for national authorities) to respond appropriately and proportionately to the presently identified and future risks, and in particular ensure that they are able to restrict, prohibit, and/or impose specific requirements or conditions, following a risk-based approach, for the supply, deployment, and operation of 5G network equipment on the basis of a range of security-related grounds.



They should in particular:

- Strengthen security requirements for mobile network operators (e.g. strict access controls, rules on secure operation and monitoring, limitations on outsourcing of specific functions, etc.);
- Assess the risk profile of suppliers; as a consequence, apply relevant restrictions for suppliers considered to be high risk - including necessary exclusions to effectively mitigate risks - for key assets defined as critical and sensitive in the EU coordinated risk assessment (e.g. core network functions, network management and orchestration functions, and access network functions);
- Ensure that each operator has an appropriate multi-vendor strategy to avoid or limit any major dependency on a single supplier (or suppliers with a similar risk profile), ensure an adequate balance of suppliers at national level and avoid dependency on suppliers considered to be high risk; this also requires avoiding any situations of lock-in with a single supplier, including by promoting greater interoperability of equipment.

For its part, the European Commission is to ensure a diverse and sustainable 5G supply chain through a combination of measures. Among the measures foreseen are controls on FDI, promotion of the EU's own 5G technology base, participation in standards efforts, and development of an EU-wide certification scheme in order to promote more secure products and processes.

The Commission subsequently made clear that it views Huawei and ZTE as *High Risk Vendors (HRVs)* in the sense meant by the Toolbox. More precisely, they stated “that decisions adopted by Member States to restrict or exclude Huawei and ZTE are justified and compliant with the 5G Toolbox”. (European Commission, 2023)

A second report on the implementation of the Toolbox claims that “A vast majority of Member States have reinforced or are in the process of reinforcing security requirements for 5G networks based on the EU Toolbox ...”; unsurprisingly, it also complains about remaining gaps. Twenty-four Member States had adopted or were preparing legislative measures giving national authorities the powers to impose “restrictions on high-risk suppliers for key assets defined as critical and sensitive in the EU coordinated risk assessment”. Of these, only ten had restrictions in place at the time.

At EU level, numerous additional measures have been taken, or are in the works, by the European Commission or the NIS Coordination Group.

Among Member States that have put restrictions in place, the approach taken by the German government – which has long hesitated to put hard restrictions in place – is nuanced, time sequenced, and instructive. The German government announced in July 2024 that it had “... reached an agreement with major telecom companies to have them stop using critical Huawei and ZTE components in their 5G mobile infrastructure in five years, the latest step by a European country to ban Chinese companies from critical telecommunications infrastructure. ... The agreement with the telecom companies —



Deutsche Telekom, Vodafone and Telefonica — comes in two steps. First, use of Chinese-made critical components will be discontinued from core parts of the country's 5G networks by the end of 2026. Then, the parts made by Chinese manufacturers will be phased out from antennas, transmission lines and towers by the end of 2029." (Schuetze, 2024)

2.3 United Kingdom

The UK government has had long-standing concerns over Huawei's large UK market share of infrastructure gear. They were worried about critical dependency. They issued guidance in 2020, and implemented a full ban in 2022.

Huawei and the UK government put in place a unique arrangement, the *Huawei Cyber Security Evaluation Centre (HCSEC)*. A team including UK experts and staff transferred from Huawei periodically evaluated the software used in Huawei infrastructure equipment. Their reports were public, but they do not appear to have published since 2021. (Huawei Cyber Security Evaluation Centre (HCSEC) , 2021)

In previous years, they typically reported that the quality was less than ideal, but that there were no systemic risks. The most recent report was more negative, in part because US sanctions had impacted Huawei's quality. (Huawei Cyber Security Evaluation Centre (HCSEC) , 2021)

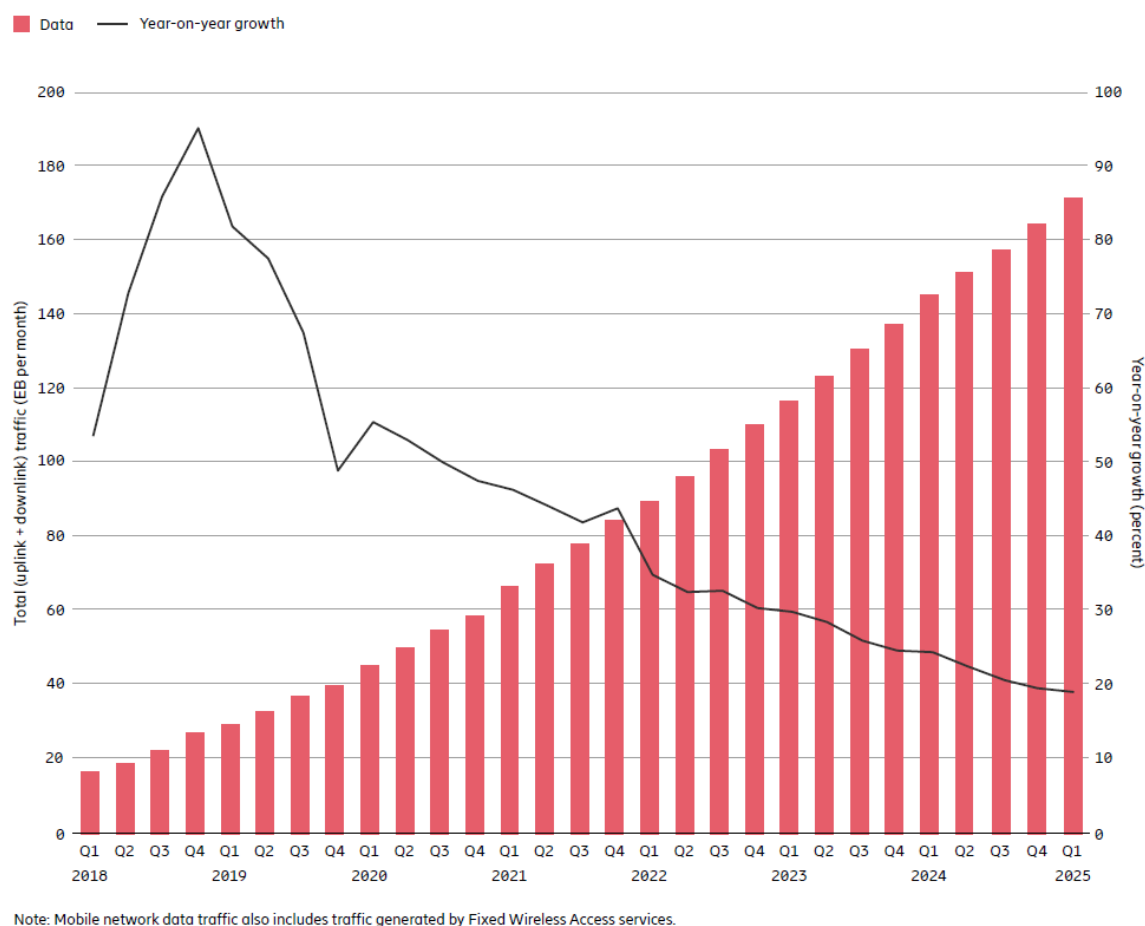


3. The overall evolution of infrastructure equipment shipments and unit prices worldwide

The mobile environment continues to grow. Growth in the number of mobile subscribers and in mobile traffic is what drives in turn growth and modernisation of mobile networks.

The growth in traffic is comprised of both growth in the number of mobile subscribers, and in growth in traffic per subscriber per unit time. The combined effect is visible in Figure 1. These data, like most data in this report, correspond to historical data up to shortly before publication of the report, coupled with market forecasts going several years into the future. Note that, while the volume of traffic continues to grow, the year over year growth in percentage terms has tended to decline over time, consistent with overall internet growth trends.

Figure 1. Global mobile network data traffic and year-on-year growth (EB per month).



Source: (Ericsson, 2025, p. 8)



We address the growth in the number subscribers together with the shift of subscriptions from 4G to 5G mobile networks in Section 3.1.

3.1 Shipments of 4G and 5G versus earlier generations

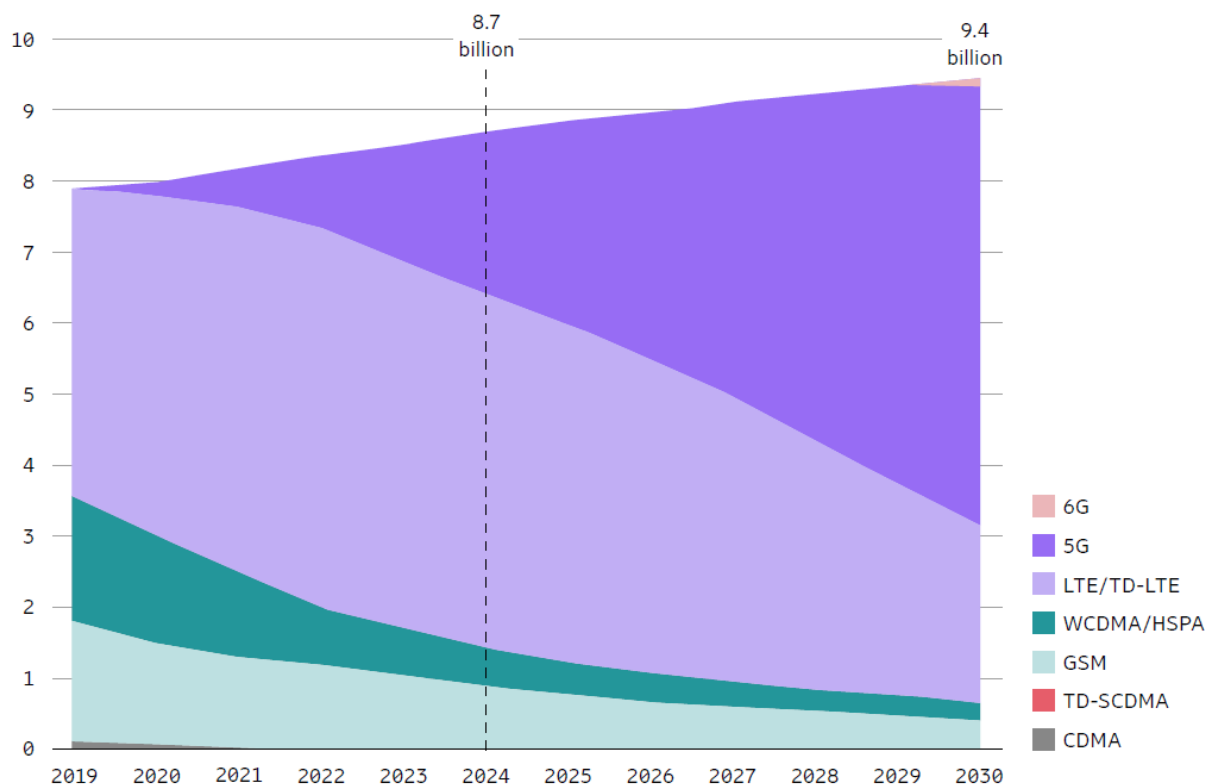
The mobile environment is in the midst of an overall transition from the fourth generation (LTE) to a fifth generation (5G). Nearly all deployments of 5G to date have been of *5G New Radio (5G NR)* systems. These 5G NR networks provide an improved *Radio Access Network (RAN)*, but are still based on the 4G Evolved Packet Core. *5G Standalone (5G SA)* networks are based on a new cloud-based core network, and are expected to provide further benefits, but it is still early days for 5G SA (Ericsson).

All of our analysis in this study is based on 5G NR networks because these represent the current standard, and these networks (and their successors) are also the networks where concerns about equipment from Chinese manufacturers have been raised. In terms of deployments, it is still early days for 5G SA.

Ericsson – both a major supplier of mobile infrastructure equipment, and a reliable supplier of estimates of the usage of mobile networks – estimates that the number of 5G subscriptions worldwide will not equal the number of 4G LTE subscriptions until 2027 (see Figure 2).



Figure 2. Mobile subscriptions by technology (billion).



Source: (Ericsson, 2024, p. 4)

Based on market research data collected by Dell'Oro, we can say that the number of large mobile base stations (*macro BTS*) shipped by the manufacturers of the equipment roughly parallels these developments, albeit with a bit of lead time relative to consumer use.¹ These are the base stations that are used to produce most mobile service.

We also have data on micro BTS and pico BTS, which can be expected to play a growing role in network densification with the shift to 5G; however, we do not report on them here. First, the volumes are less, and thus the revenues considerably less, than for macro BTS; second, our perception is that they are not as much of a commoditised product as macro BTS, thus harder to compare.

3.2 Market shares worldwide

There are a large number of equipment manufacturers; however, in practice there are only five that matter in terms of overall market structure. These are Huawei, Ericsson, Nokia, Samsung, and ZTE, with

¹ The Dell'Oro data correspond to historical data up to shortly before publication of a Dell'Oro report, coupled with market forecasts going several years into the future.



global revenue shares in that order. Historically, it was natural to think of the market for mobile equipment as being global in scope. Today, this is no longer the case – the market for 5G NR mobile equipment is hugely differentiated by region of the world, due in large measure to the restrictions on the use of mobile infrastructure equipment from China. This becomes a core issue in Chapter 4.

3.3 Unit price trend over time

For our purposes, ASP is an excellent measure of the unit price. What is visible in the Dell'Oro data is that the unit price of LTE macro BTS was rather high when they were first introduced, then dropped and stabilised. This presumably reflects some combination of the manufacturers climbing the learning curve, their achieving economies of scale, and also the expected Moore's Law improvements in the price/performance of semiconductors. These reductions in unit price eventually stabilised – they did not continue indefinitely. Indeed, there was some upward drift of unit price in 2019 through 2022 for reasons that are not entirely clear, followed by a return to the previous values.

For 5G NR macro BTS, a somewhat similar pattern is visible, but the decline in ASP to a stable level similar to that of 4G LTE macro BTS was very rapid. Again, prices elevated a bit in 2021 and 2022.



4. The overall evolution of infrastructure equipment shipments and unit prices by region and by supplier

In this chapter, we take the analysis to a deeper level, and provide rough estimates of shipment volumes and unit prices for selected countries by vendor.

In order to calculate ASP with any granularity below the level of worldwide estimates, we need to know *both* the total revenue and the total number of units to which it corresponds. As good as the Dell'Oro data are, they do not provide estimates of shipment quantities by region. Consequently, we invested a fair bit of effort to estimate the number of units sold in selected regions in a different way, as we explain in Section 4.1. We then go on to discuss revenue and market shares by region and supplier, and ASP in selected regions by supplier.

4.1 Shipments of 5G macro BTS by region

Since the Dell'Oro does not provide BTS shipments by region, and we were unable to identify a reliable source of shipments of macro BTS by region, it was necessary to estimate shipments in a different way.

We estimated shipments of 5G NR base stations (BTS) by region per quarter by rolling up estimates of the number of 5G bases deployed, based on data provided in periodic reports issued by the EU's *5G Observatory*. In Table 1, the leftmost column indicates the number of the report from which the data came.

A graphic representation of the same data appears in Figure 3. We depict it using logarithmic scale because otherwise the huge disparity between Chinese deployments and those of the rest of the world would make it impossible to see deployment trends elsewhere.

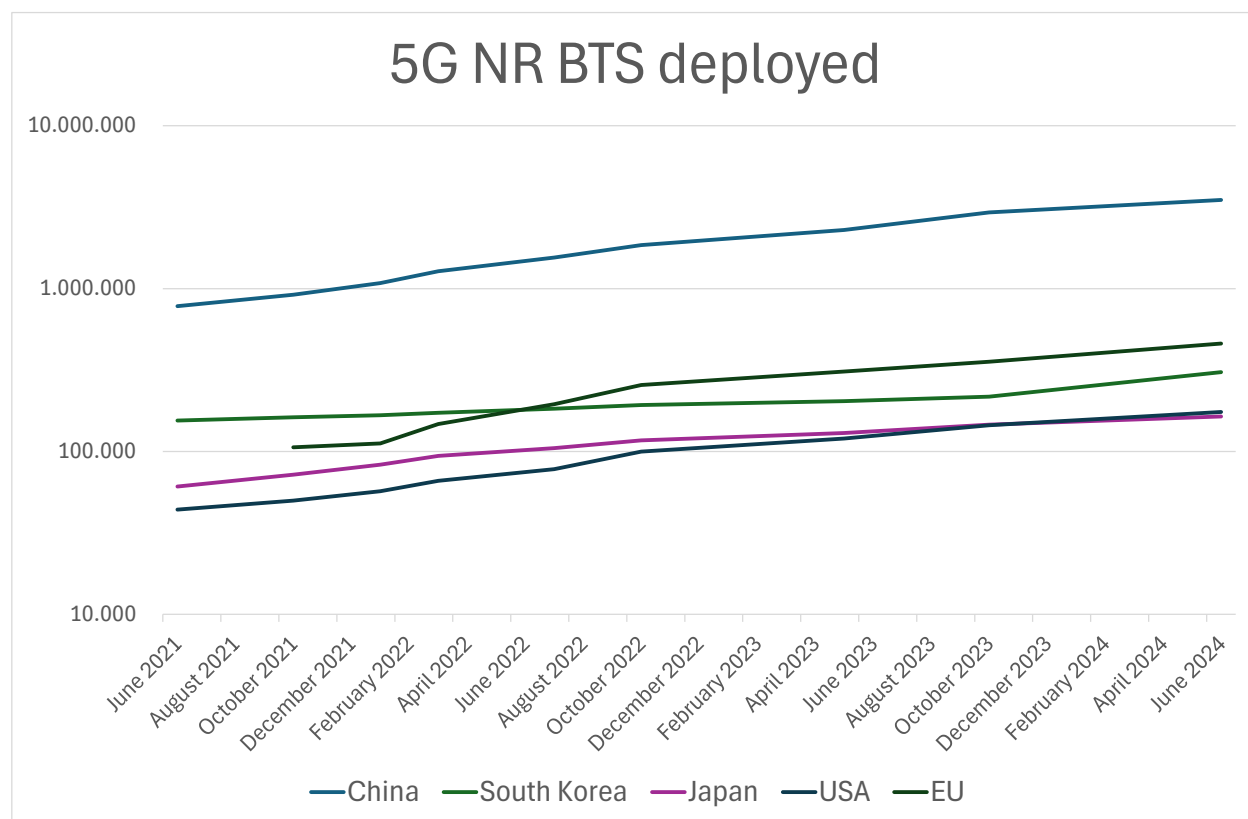
Table 1. Estimated number of 5G NR macro BTS deployed (2020 - 2024).

Report	Date	China	South Korea	Japan	USA	EU
8	June 2020	250,000				
11	March 2021	700,000	150,000	50,000	40,000	
12	June 2021	700,000	150,000	50,000	40,000	
13	October 2021	916,000	162,000	50,000	50,000	106,000
14	January 2022	916,000	162,000	50,000	50,000	112,000
15	March 2022	916,000	162,000	50,000	50,000	147,308
16	July 2022	916,000	162,000	50,000	50,000	147,308
17	October 2022	1,850,000	215,000	50,000	100,000	256,074
18	May 2023	2,290,000	215,000	50,000	100,000	309,342
19	October 2023	2,937,000	217,000	146,000	100,000	356,000
20	June 2024	3,500,000	307,000	146,000	175,000	460,000

Source: Author's summary based on *5G Observatory* quarterly and semi-annual reports 8 through 20.



Figure 3. 5G NR Base Stations deployed, by region (June 2021 - June 2024)



Source: Author's elaboration, based on *5G Observatory* quarterly and semi-annual reports 11 through 20

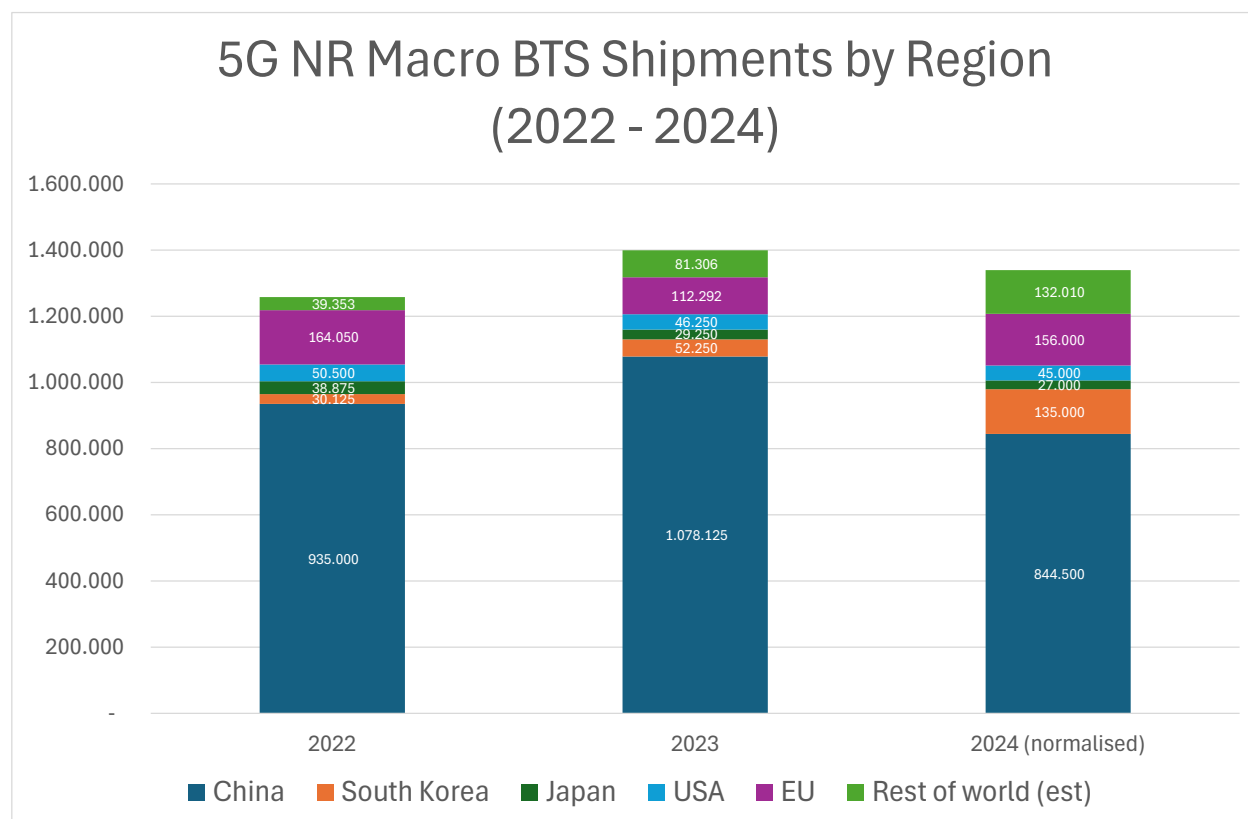
Note, however, that this is the *stock* of base stations rather than the *flow* – for many of our estimates, the flow is what we would ideally want. Since it is reasonable to assume that 5G NR base stations are going in, and hardly any are coming out just yet, the change in the number deployed from one period to the next can be assumed to correspond to the number of units shipped; however, we allow for about a quarter of lag between shipment and deployment.

It is often the case that the *5G Observatory* data does not change for several successive quarters. Those appear as numbers in *italics* in Table 1. In converting those numbers to shipment volumes per quarter, we used “eyeball interpolation”.

The corresponding shipment volumes for China, South Korea, Japan, the USA, and the EU appear in Figure 4.



Figure 4. 5G NR Base Stations shipped, by region (2022 - 2024).



Source: Author's elaboration, based on *5G Observatory* quarterly and semi-annual reports 11 through 20, plus Dell'Oro data lagged one quarter for rest of world estimates.

In order to estimate shipments to regions other than those explicitly tabulated by the 5G Observatory, we compared worldwide shipments to the sum of those in the 5G Observatory reports. The data do not perfectly align, the most likely reason for the mismatch being that Dell'Oro is reporting shipments, while the 5G Observatory is reporting the number of macro BTS deployed in the field. Deployment does not take place instantaneously. We lagged the Dell'Oro data forward by one quarter, which visually improved the fit; however, the reality is most likely that the delay in deploying individual BTS needs to be thought of as a random variable whose distribution cannot easily be discerned from data at hand.

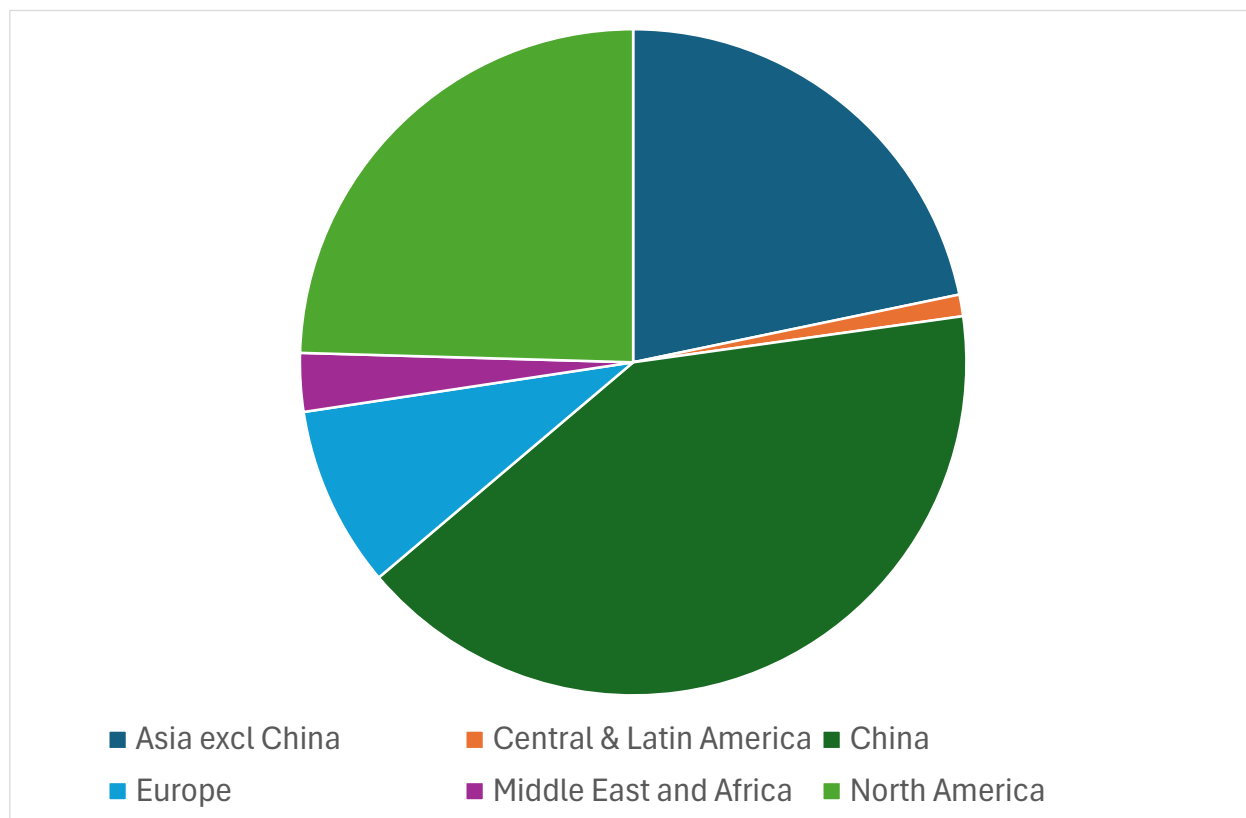
For that reason, we chose instead to estimate ASP for China and the USA using a method that is coarser, but simpler and more robust (see Section 4.3). We work from the totality of all 5G shipments over the period 2018 to 2023 (the range of our reliable data).



4.2 Revenue shares by region for key vendors

When one looks at 5G NR RAN manufacturing revenue worldwide at a coarse level and for all vendors combined (see Figure 5), nothing seems to be particularly amiss. China and the rest of Asia represent a large share of revenue to suppliers, also North America in some years, the EU somewhat less.

Figure 5. 5G NR RAN revenue share by region (all vendors) (combined 2018 - 2023).



Source: Author's elaboration, based on (Dell'Oro Group, 2024).

Swimming just below the surface, however, are large asymmetries among the suppliers of infrastructure equipment. Huawei and ZTE have sold no 5G NR mobile infrastructure equipment at all in North America; by contrast, nearly all of ZTE's 5G NR income has been earned in China, and the majority of Huawei's as well (Dell'Oro Group, 2024).

An industry contact recently told this author that, in terms of revenue, Ericsson has become an American rather than a European company. Revenue data tend to bear this out; however, Ericsson sales in Asia are substantial in some years, and their sales in China are not negligible (Dell'Oro Group, 2024).



Nokia has a relatively balanced distribution of shipments, but the same is not true of other vendors. Nearly all of Samsung's revenue derives from sales to North America and to non-China Asia, while the remaining small suppliers sell mainly to Asia (including China). (Dell'Oro Group, 2024)

4.3 Revenue shares by vendor in key regions

If we look at the same data in a different way, we can see the supplier market shares by 5G NR RAN manufacturing revenue over substantially the entire lifetime of 5G NR (from 2018 to as close as possible to the present) for each of the regions covered by (Dell'Oro Group, 2024). This includes China, where Chinese suppliers are obviously not restricted, and North America (larger than the USA), where they have been totally excluded.

For North America, nearly all 5G NR macro BTS are supplied by Ericsson, Nokia and Samsung, with revenue shares in that order. For China, most 5G NR macro BTS are supplied by Huawei and ZTE. (Dell'Oro Group, 2024)

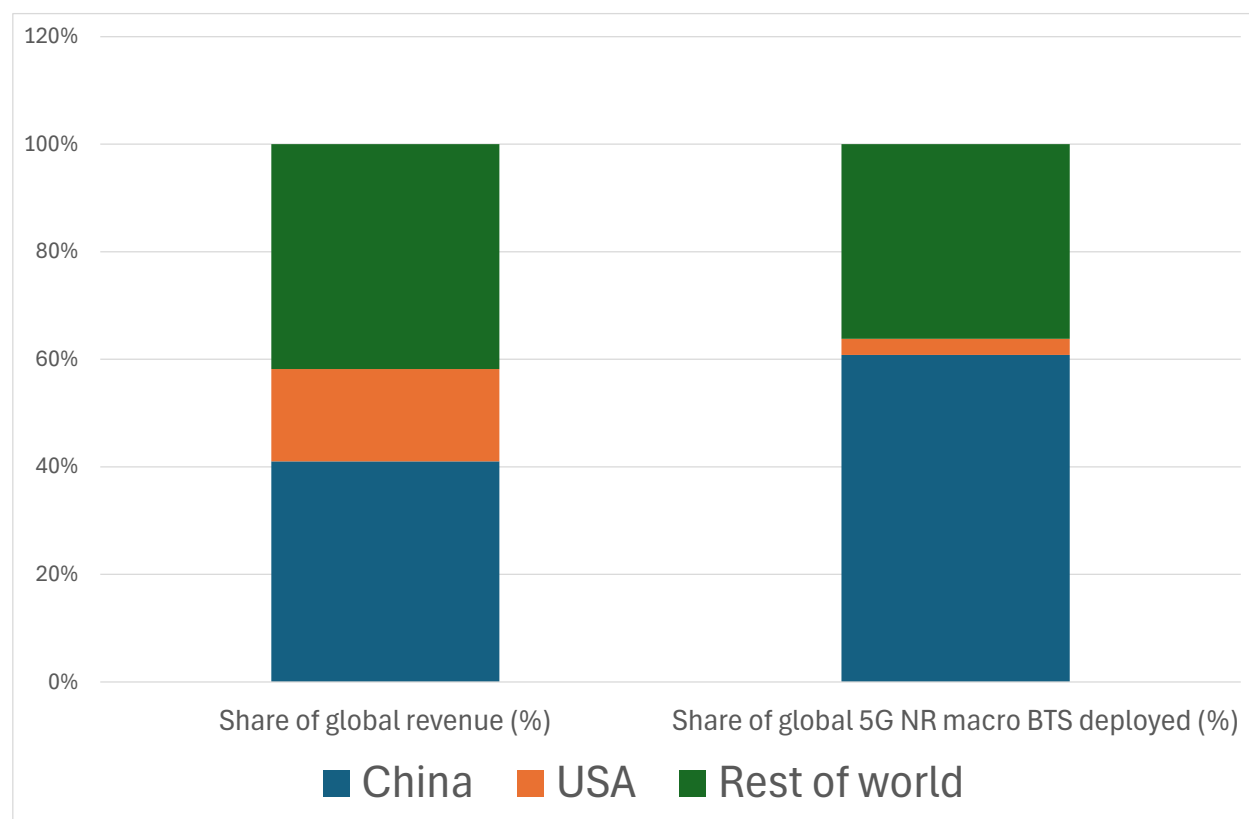
4.4 Average selling price (ASP) by region and supplier

Lack of comprehensive and fully cross-comparable quantity data makes ASP calculations at regional level challenging, but reasonably robust calculations can be made for China and for the USA.

If we look at total 5G NR manufacturing revenue over the lifetime of 5G by region (Dell'Oro Group, 2024) and compare it to the number of 5G NR base stations that had been deployed up until the middle of 2024 based on 5G Observatory data, it immediately becomes obvious that something strange is going on. The estimated fraction of global 5G NR manufacturing revenue that the USA is paying (after some adjustments, as we explain shortly) is about 17% of the global total, but the fraction of global BTS that the USA has deployed is about 3% of the global total (see Figure 6). All else being equal, this would seem to imply that the USA is paying up to six times as much per macro BTS as the rest of the world. The same data also suggest that the unit price in China is lower than the global average.



Figure 6. 5G NR macro BTS revenue and 5G NR macro BTS deployed (cumulative 2018 – 2023) (global share in %).



Source: Author's elaboration, based on (Dell'Oro Group, 2024) and 5G Observatory data.

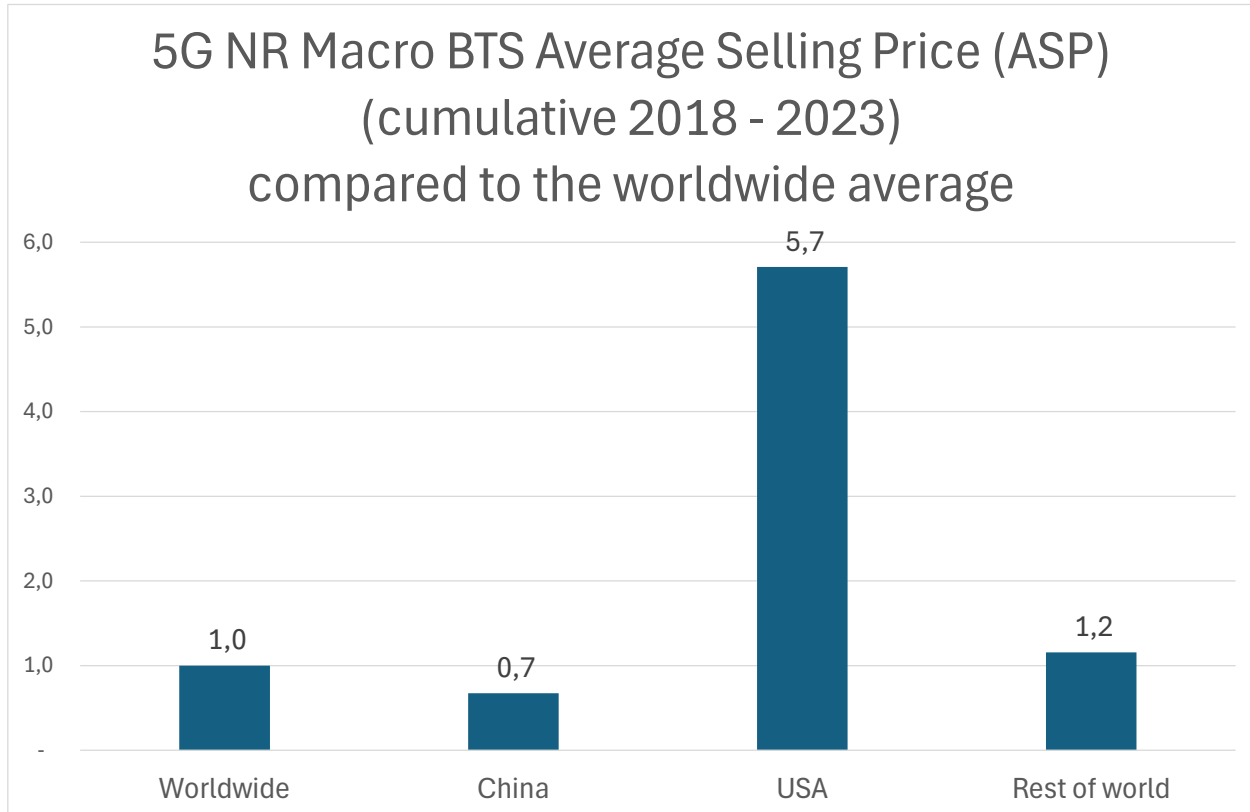
For the world as a whole, for China, for the USA, and for the rest of the world, the ASP per macro BTS can be computed or estimated (see Table 2). Revenue figures for 5G NR are available for the world, for China, and for North America in (Dell'Oro Group, 2024). The number of BTS globally as of the end of 2023 comes directly from (Dell'Oro Group, 2024), while the USA and China figures come from the EU's 5G Observatory, adjusted to make them reflect the end of 2023. As a global average, between roughly 90% of 5G NR manufacturing in each of the past few years has been macro BTS revenue (Dell'Oro Group, 2024). In order to align revenue estimates for North America with macro BTS counts in the USA, we assume that 70% of North American macro BTS revenue is associated with the USA (the rest corresponding to Canada, Mexico, and smaller North American markets).

The price differences that this calculation identifies are far more than might have been expected (see Figure 7). The USA 5G NR macro BTS ASP is 5.7 times as high as the global ASP, and 8.5 times as high as the ASP in China. As previously noted, we have less than full confidence in the 5G Observatory estimate



of 5G NR macro BTS deployed to the US, so cannot exclude that an error accounts for some, but not all, of this huge ratio.

Figure 7. 5G NR macro BTS Average Selling Price (ASP) for China, the USA, and the rest of the world (cumulative 2018 – 2023) relative to the worldwide average over the same period.



CAVEAT: If the 5G Observatory underestimated the number of 5G NR macro BTS deployed to the USA, as might well be the case, then this estimate for the USA is even higher than the still-high true figure.

Source: Author's elaboration, based on (Dell'Oro Group, 2024) and 5G Observatory data.

It turns out that the USA macro BTS ASP is about four times as high as the global ASP for Ericsson, Nokia and Samsung, respectively, which is surprising to the extent that it seems to imply that the charge MNOs in the USA far higher prices that they charge globally. By contrast, it is about eight times as high as the global macro BTS ASP for Huawei and ZTE.

We believe that the mechanics of what is happening can best be understood as comprising two distinct time periods 2012 – 2018, and 2018 to the present. The years 2018 – 2019 represent an inflection point



Working Paper

between them, for two reasons: first, the beginning of 5G NR shipments; and second, and probably more important, the beginning of restrictions imposed on Chinese vendors imposed in the USA (see Section 2.1).

In general, we would expect unit prices to decline over time as a result of Moore's Law. This was largely the case for the period 2012 – 2018, the era before 5G NR appeared and before restrictions on Huawei and ZTE appeared. This is visible in the column "2012 - 2018 Mfg ASP CAGR" of Table 2. The aggregate *Compound Annual Growth Rate (CAGR)* for all vendors is -5.0%, and every single vendor demonstrates a negative CAGR for macro BTS. Not only was the worldwide CAGR of the macro BTS ASP negative for all suppliers, but it was somewhat similar for all suppliers.

For the period 2018 – 2023, however, macro BTS ASP increases for every vendor except Huawei.

This makes sense when one first considers that the worldwide ASP for each supplier is a linear combination of the ASP for the USA (where restrictions were effectively total) and the rest of the world (where they were mixed). The gradual increase in the global average ASP for 5G NR macro BTS for Ericsson, Nokia, and Samsung could be understood as reflecting their growing confidence that they can win sales at a higher price in North America because they face no aggressive competition.

One might have supposed that the increase in CAGR for the other vendors reflects the greater cost of 5G equipment compared to previous generations, but the Huawei unit price trend argues otherwise. The CAGR of Huawei's ASP continues on the previous track because for them, in the countries where they are still permitted to sell, not much has changed – their competitive situation is largely the same wherever they are permitted to compete. They thus serve as a benchmark, reflecting where unit price trends might have gone in the absence of restrictions.

Table 2. The shifting trend in macro BTS (all technologies) ASP across the different suppliers (2012 - 2023).

	2012 - 2018 Mfg ASP CAGR	2018 - 2023 Mfg ASP CAGR	2012 - 2023 Mfg ASP CAGR
Aggregate	-5.0%	0.8%	-2.4%
Ericsson	-6.9%	4.5%	-1.9%
Huawei	-2.0%	-2.6%	-2.3%
Nokia	-0.8%	1.1%	0.1%
Samsung	-8.2%	13.2%	1.0%
ZTE	-11.2%	9.0%	-2.5%

Source: Author's elaboration, based on (Dell'Oro Group, 2024).



5. Transition issues where restrictions have been introduced

There are practical lessons to be learned from the rip and replace work in the USA, and also from ongoing efforts in the EU.

5.1 The need for parallel operation during transition

The transition is not as simple as policymakers might like to think.

For most if not all MNOs, a “flash day” cut-over would be unthinkable. The transition will take place in stages. The experience has been that it typically takes several years, and entails a great deal of complexity.

This implies parallel operation of old and new equipment. The firms that produce the equipment invest a great deal of effort in ensuring that a seamless upgrade is possible as long as the MNO sticks with their equipment. They have no incentive to make it easy to transition to another vendor’s equipment – quite the contrary! The technology is evolving in a direction that seeks to enable more “mix and match” with a technology known as *Open RAN*, but we are not there yet.

This implies that interoperability problems are to be expected during the transition, and this appears to be the reality. (Kang, 2023)

5.2 Impact on Operational Support Systems and Business Support Systems

Those who have not worked for a network operator will tend to underestimate the amount of investment that has to go into a wide range of *Operational Support Systems (OSS)* to deal with faults and keep the network running, and *Business Support Systems (BSS)* to deal with customer provisioning, billing and the like.

Many of these systems are provided by the equipment vendor. Even if this is not the case, there are sure to be equipment dependencies in the OSS.

Deutsche Telekom Group CEO Tim Höttges explains: “By 2029, we have to develop proprietary, sovereign software which is steering and configuring all the antennas. All the software which is required to run the access nodes, so the antennas, has to come from the operators. So we are not using software from third parties anymore ... Now, this requires a totally new skill. You cannot buy that software on the global market now ... we have to develop that software.” Höttges said the cost of the software alone would be a “triple million number.” (Morris, 2024)



6. Impact of total mobile network cost on societal welfare

In considering societal welfare implications, we need to consider, first and foremost, how these increased mobile infrastructure costs relate to the total costs experienced by mobile network operators (MNOs). Second, we need to consider how these prices flow into prices paid by consumers. And third, how do these changes in retail prices translate into altered consumption (i.e. price elasticity).

These factors could in theory enable a rough assessment on the impact on consumer, producer, and societal welfare using the classic Harberger methodology; we have not attempted to work that out in full here because there are so many uncertainties in the data; however, we provide some general thoughts as guidance for possible future analyses.

6.1 Mobile infrastructure costs as a fraction of total costs

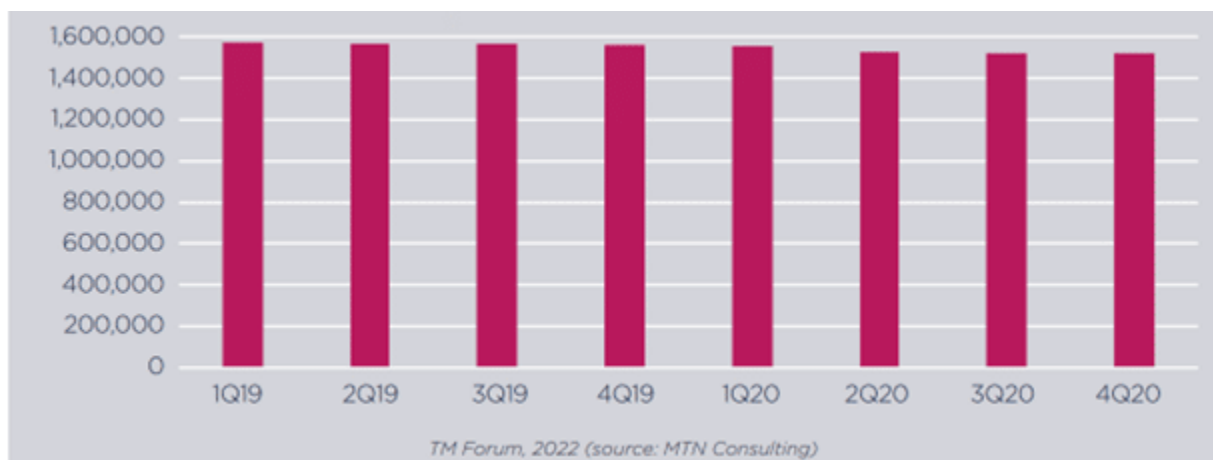
In previous work, this author did a similar analysis of the fixed network. (Marcus & Monti, 2011) It was fairly easy to find well-grounded analyses of the cost breakdown of the network, since EU national regulatory authorities were obliged to oversee regulatory cost modelling in order to set cost-based prices for network elements such as unbundled local loops. For the mobile network, it is harder to find such a treasure trove of reliable data.²

Nonetheless, a few sources are available, and they suffice for our limited purposes. For operating expense (OPEX) and capital expense (CAPEX), a report by TM Forum (Newman & Ramsay, 2022) provides useful headline figures as of 2019 to 2021. Global OPEX ran about \$1,500 bn per year (Figure 8), while global CAPEX ran about \$300 bn per year (Figure 9), suggesting that CAPEX is on average about one sixth as great as OPEX. Meanwhile, Figure 10 identifies key components of OPEX.

² Some work is done at EU level to set EU-wide call termination rates and wholesale mobile roaming prices.



Figure 8. Total MNO OPEX worldwide (\$ mn) (1Q2019 - 4Q2020).



Source: (Newman & Ramsay, 2022, p. 25)

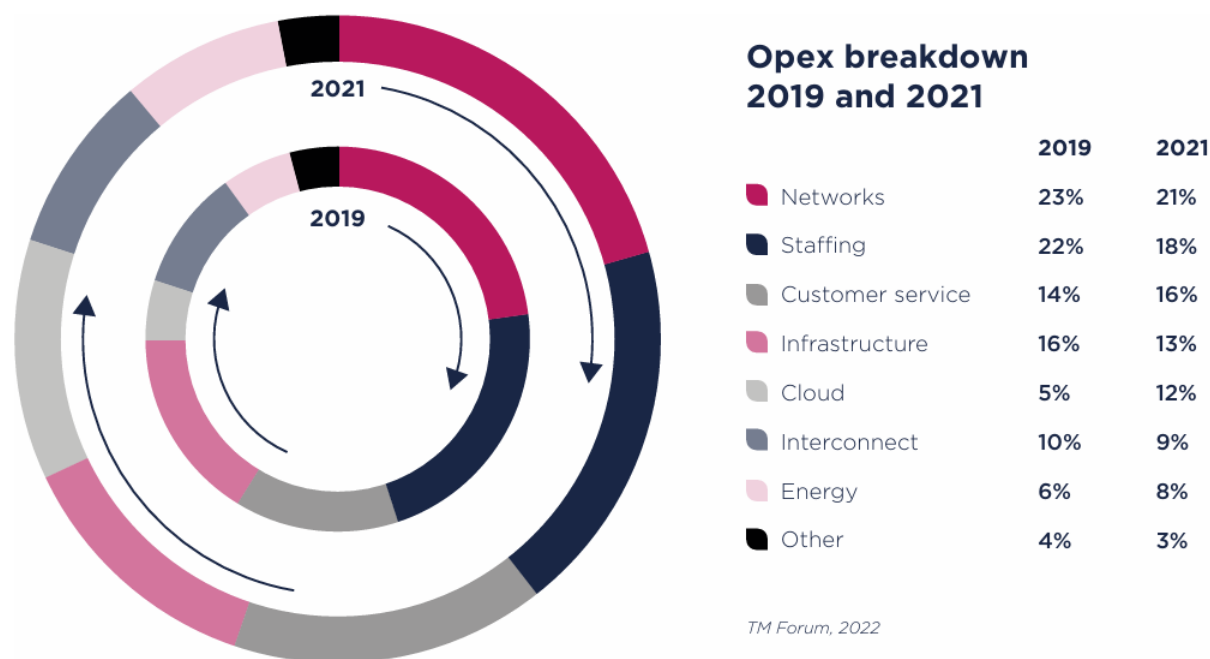
Figure 9. Total MNO CAPEX worldwide (\$ mn) (1Q2019 - 4Q2020).



Source: (Newman & Ramsay, 2022, p. 25)



Figure 10. Breakdown of MNO OPEX (2019 and 2021).



Source: (Newman & Ramsay, 2022, p. 26)

But how does the elevation of mobile RAN infrastructure cost relate to total cost? For this, we prefer to work from a longer CAPEX time series, and one that is not so heavily dependent on the years of the COVID-19 pandemic. Figure 11 was provided by Analysys Mason in a summary of one of their reports.³ Comparing these data to the totality of 5G NR manufacturing revenues worldwide (Dell'Oro Group, 2024), the worldwide manufacturing revenues for new RAN equipment represent 19 – 25% of CAPEX on average once deployment hits its stride in 2021 (see Figure 18).

³ The estimates are significantly lower than those of TM Forum, with the likely explanation being that Analysys Mason did not include the cost of spectrum in their CAPEX calculation.



Figure 11. Total MNO CAPEX worldwide excluding spectrum (2016 - 2025).



Source: (Gabriel, 2017)

This implies that RAN expenditures represent about 2 per cent of total MNO expenditures in the normal course of events. Recall, however, that this is a global average, and that deviations in individual countries could be large.

Notably, for countries where there is a total exclusion of Chinese gear, this probably greatly understates the impact. The US experience suggests that total exclusion leads to unit costs for 5G NR BTS that might be up to as much as five or six times higher than they would be in a fully competitive market, and we assume here that the over-pricing would carry through to all products and services from the same manufacturers. This would suggest that if MNOs continued to purchase as they normally would, over-priced RAN infrastructure equipment would constitute something like 60% of CAPEX (still excluding spectrum), or 44% of CAPEX when spectrum is included, or something like 10% of the sum of CAPEX plus OPEX.

In reality, however, the increase in price will have two effects. On the one hand, it will raise MNO expenditures per year; on the other, the MNOs will tend to buy fewer BTS per year as a kind of wholesale price elasticity response. Total annual RAN equipment manufacturing revenue to North America “only” doubled from 2016 to 2022 (with part of the increase due to inflation) (Dell'Oro Group, 2024). That they increased less than the apparent increase in unit prices for mobile infrastructure equipment would tend to support the view that the rate of deployment in North America slowed, and thus suggest that the estimate of the 5G Observatory might not be too far off.



6.2 Impact on consumer prices and societal welfare

In Section 6.1, we noted that the increased ASP for macro BTS will result in higher unit cost for the MNOs, but also will slow the rate at which they purchase due to the price elasticity of MNO demand for network enhancements. In the absence of this effect, consumer prices could be expected to increase by some $11\% - 2\% = 9\%$, assuming that the cost increase to MNOs translates directly into retail price increases. The manufacturing revenue data for North America show a sizable increase after restrictions on Chinese gear were introduced in the USA starting in 2019, but a bit less than a doubling rather than a quintupling, thus suggesting that this tendency to stretch out purchases is substantial (Dell'Oro Group, 2024).

In reflecting on the impact on consumer welfare and producer welfare, geography needs to be taken into account. Under the classic Harberger Triangle analysis, it is generally assumed that societal welfare is the sum of consumer welfare and producer welfare. Over-pricing leads to a transfer of welfare from consumers to producers – societally neutral, in theory, since total welfare does not change – and a deadweight loss constituting consumption that could have happened but did not because less of the goods or services in question were consumer to the elasticity response to the over-pricing (the Harberger Triangle). In this case, however, the consumers and the producers are not necessarily located in the same country! Two of the three main producer beneficiaries are located in the European Union (Ericsson and Nokia), whereas the consumers directly affected by a total exclusion are mostly in North America.



7. Summary and concluding observations

In this report, we have established clearly that unit price as measured by Average Selling Price (ASP) for 5G macro BTS in the USA is high compared to worldwide prices, and also high compared to unit prices in China. Furthermore, the worldwide average ASP for all major producers (other than Huawei) increased after Huawei and ZTE were blocked from selling in the USA (and in effect in all of North America).

The effect is larger than what we might have expected. The USA macro BTS ASP appears to be 5.7 times as high as the global ASP, and 8.5 times as high as the ASP in China. We caution that this may over-state the effect somewhat – if the 5G Observatory underestimated the number of 5G NR macro BTS deployed to the USA, that would bias these ratios upwards. This effect cannot account fully for the high pricing that we see, however, since otherwise the combined number of 5G NR macro BTS globally, which is known from multiple sources.

That the USA macro BTS ASP appears to be about much higher than the global ASP for Ericsson, Nokia and Samsung is surprising to the extent that it seems to imply that they charge MNOs in the USA far higher prices that they charge globally.⁴

As we note in Section 6.2, MNOs would not respond to such a great increase in price by simply increasing their expenditure per year proportionately. They would expend more per year, but they would also slow their purchases or reduce them overall as a price-elasticity response. The data suggest that this has happened in the United States.

These differences are large, far larger than expected, but one must still remember that these are not the only costs that MNOs experience. First, the global trend seems to be that MNO OPEX is about six times greater than MNO CAPEX.

We estimate that worldwide manufacturing revenues for new RAN equipment represented 19 – 25% of CAPEX on average once deployment hits its stride in 2021 (see Section 6.1).

As we explained in Section 2.1, the total value of mobile RAN equipment of all technologies sold by Huawei and ZTE into North America (thus not only the USA but also Canada, Mexico and more) from 2012 to 2023 according to Dell'Oro data about \$1.5 billion for Huawei and ZTE together. The FCC estimates the cost of replacing this gear at just under \$5 billion, thus three times as great as the original purchase price, which one again tends to be consistent with a large increase in unit cost for 5G NR infrastructure equipment.

The equivalent cost if a “rip and replace” of Chinese gear in the EU might be far greater because it would entail a much greater volume of installed Chinese equipment. Implicit in our thinking is that, if EU countries were to implement supplier restrictions as stringent as those in the USA, that prices paid by

⁴ Note that the ASP for the world excluding North America would be lower than the global ASP (because North America is included in the global figures) – a comparison of the USA ASP to the ASP for the rest of the world would be even more lopsided.



MNOs for infrastructure equipment would increase to a similar degree due to (1) disappearance of the suppliers with the best price/performance characteristics, and (2) reduced competition – only three major suppliers would remain for those countries, producers would price higher as a result, and some tacit collusion might well reinforce that tendency.

7.1 Assumptions and caveats

There are many assumptions in our work.

- We rely on estimates from the *5G Observatory* for volumes of 5G NR macro BTS installed. Errors would throw off a number of calculations. We do not entirely trust their estimates for the USA; however, we have enough other indicators that suggest that errors, if any, cannot be so large as to invalidate the main findings.
- We tacitly assume that price trends for all mobile goods and services from these five major suppliers would tend to follow the same general trends as for the 5G NR macro base stations.
- We tacitly assume that 5G macro BTS are more or less a fungible commodity. This is perhaps close enough to being correct – each macro BTS typically covers a full 360 degrees (three sectors), and must serve all of the users and all of the traffic that is present. But some industry sources tell us that Huawei equipment has about 30% more reach, and a product review by a respected independent evaluator (Red Dot) tends to confirm greater range.⁵ If so, that would imply that Huawei gear covers about 1.9 times as much territory, which would in turn imply that on average only a bit more than half as many Huawei macro BTS would be needed to cover a given area as other BTS. And there may be other differences that deserve to be taken into account.
- Our main focus in this report is on equipment costs. We note that other costs are relevant, including the cost of adapting Operational Support Systems (costs that those who have not worked in the industry would tend to underestimate), mainly in Chapter 5, but we have not reflected them in our quantitative estimates.

7.2 Implications for public policy

Our focus in this study has been on estimating the increased cost of full restrictions on the use of Chinese gear, and we have found that the cost is high – much higher than expected in fact. But we have not attempted a comprehensive assessment of the implications for public policy.

With that said, we feel compelled to add that the key recommendation of the EU's Toolbox impresses us as being sensible and balanced. It calls on EU Member States to "assess the risk profile of suppliers; as a

⁵ Per the Red Dot jury: "The base station Huawei 5G MetaAAU not only impresses with its pioneering performance but also with elegance and an easy installation." They go on to note: "The Huawei 5G MetaAAU base station utilises the ELAA technology (Extremely Large Antenna Array) for enhanced signal quality, thereby extending the coverage while simultaneously reducing the number of sites. The simple installation process boosts the efficiency of 5G network construction, while costs and energy consumption are lowered. The robust CMF selection ensures an attractive appearance that seamlessly integrates into various environments."



Working Paper

consequence, apply relevant restrictions for suppliers considered to be high risk - including necessary exclusions to effectively mitigate risks - for key assets defined as critical and sensitive in the EU coordinated risk assessment (e.g. core network functions, network management and orchestration functions, and access network functions).” This might imply full restriction, or might not, depending on the outcome of rigorous risk assessment and analysis.



8. References

- 5G Observatory. (2024). *5G Observatory Biannual Report: Report of June 2024 (Situation as of 31 March 2024)*. European Commission. Retrieved from https://5gobservatory.eu/wp-content/uploads/2024/07/BR-20_5G-Observatory-Report-June-2024-2.pdf
- Cullen International. (2024). *Mitigating Risks from High-Risk Suppliers in Telecom Networks*.
- Dell'Oro Group. (2024). *Mobile RAN Quarterly Report 1Q24, vol. 25, no.1, M1A*. Dell'Oro Group.
- Ericsson. (2024). *Ericsson Mobily Report: November 2024*. Ericsson. Retrieved from <https://www.ericsson.com/4adb7e/assets/local/reports-papers/mobility-report/documents/2024/ericsson-mobility-report-november-2024.pdf>
- Ericsson. (2025). *Ericsson Mobility Report: June 2025*.
- Ericsson. (n.d.). *Experience 5G without limits*. Retrieved from <https://www.ericsson.com/en/5g/5g-sa>
- European Commission. (2023, June 15). *Communication from the Commission: Implementation of the 5G cybersecurity Toolbox*. Retrieved from <https://digital-strategy.ec.europa.eu/en/library/communication-commission-implementation-5g-cybersecurity-toolbox>
- Gabriel, C. (2017). *Mobile Operator CAPEX Spending: Worldwide Trends and Forecasts 2016–2025*. Analysys Mason. Retrieved from https://www.analysysmason.com/globalassets/x_migrated-media/media/analysys_mason_mobile_capex_forecast_dec2017_sample_rdns04.pdf
- Huawei Cyber Security Evaluation Centre (HCSEC) . (2021, June). *Huawei Cyber Security Evaluation Centre (HCSEC) Oversight Board Annual Report: A report to the National Security Adviser of the United Kingdom*. Huawei Cyber Security Evaluation Centre (HCSEC). Retrieved from https://assets.publishing.service.gov.uk/media/60f6b6be8fa8f50c7a1b9ffd/2021_HCSEC_OB_REPORT_FINAL__1_.pdf
- Kang, C. (2023, May 9). ‘Rip and Replace’: The Tech Cold War Is Upending Wireless Carriers. *New York Times*. Retrieved from <https://www.nytimes.com/2023/05/09/technology/cellular-china-us-zte-huawei.html>
- Marcus, J., & Monti, A. (2011). *Network Operators and Content Providers: Who Bears the Cost?* WIK. Retrieved from <http://www.ssrn.com/abstract=1926768> or <http://dx.doi.org/10.2139/ssrn.1926768>
- Morris, A. (2024, August 8). Deutsche Telekom looks ahead to a post-Huawei future. *Light Reading*. Retrieved from <https://www.lightreading.com/finance/deutsche-telekom-looks-ahead-to-a-post-huawei-future>



Working Paper

- Newman, M., & Ramsay, D. (2022). *Telco to Techco: CAPEX and OPEX implications*. TM Forum. Retrieved from https://d1a5bopfc3yb9e.cloudfront.net/reports/TMForum_Telco_to_Techco_benchmark.pdf
- NIS Cooperation Group. (2020). *Cybersecurity of 5G networks: EU Toolbox of risk mitigating measures*.
- Rosenworcel, J. (2024, May 2). Letter from J. Rosenworcel (FCC) to Senator M. Cantwell. Retrieved from <https://docs.fcc.gov/public/attachments/DOC-402312A1.pdf>
- Schuetze, C. (2024, July 11). Germany to Strip Huawei From Its 5G Networks. *New York Times*. Retrieved from <https://www.nytimes.com/2024/07/11/business/huawei-germany-ban.html>

