Economic assessment of C-band reallocation in the Arab States region

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Contents

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Executive Summary

Consumer demand for mobile data has increased in the last decade, and continues to increase. Globally, mobile data traffic doubled between 2012 and 2013.[1] This growth has been fuelled by a dramatic shift in the way that video content is consumed, with people relying more and more on the internet to access news and entertainment.

For the Middle East and Africa in particular, Cisco projects that mobile data traffic will grow 14-fold from 2013 to 2018, and that video traffic will account for 76% of mobile data traffic in the region by 2018, compared to 50% at the end of 2013.

Mobile operators will need to expand capacity to cater to this demand. While more efficient use of the current spectrum can deliver some of the capacity, it is likely that the rest will need to be delivered by reallocating spectrum to mobile use. C-band spectrum (3.4-4.2GHz) appears to be well suited to provide additional capacity in urban areas, and some portion of it could help alleviate this expected spectrum scarcity.

The Arab States use a significant proportion of C-band spectrum to provide various satellite-based services, including TV distribution.[2] While the principal method of TV distribution in Arab States (direct-to-home) uses Ku-band, terrestrial TV is distributed to broadcast towers using C-band. Mobile operators and TV networks are likely to have earth stations operating in C-band, and these are used as hubs for TV contribution and distribution, and global connectivity.[3]

Reallocating C-band spectrum from its current use to mobile would involve some costs to satellite operators. We model these as one-off costs of reallocating a share of C-band spectrum from satellite to mobile usage. This cost is then compared with the cumulative value of economic benefits derived from C-band spectrum by mobile operators in the Arab countries.

For the purposes of this analysis, we assume that only half of the available C-band spectrum would be reallocated to mobile. Specifically, we assume that 400 MHz in the lower half of the C-band would be reallocated. The future demand for satellite services currently provided in C-band would therefore be met through a combination of the remaining 400 MHz of C-band and by moving their operations to alternate frequency bands such as Ka band and Ku band or by migrating to alternative platforms.

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1 Ericsson Mobility Report, June 2013. Available at http://www.ericsson.com/res/docs/2013/ericsson-mobility-report-june-2013.pdf

2 A part of C-band is used by fixed-wireless operators (FWA). We do not explicitly estimate the costs of reallocation of these operators, which we do not expect to be significant because i) most FWA services are provided by mobile operators and given that the spectrum will be reallocated back to them, the cost of reallocation is not additional; and ii) for operators that solely provide FWA services, their spectrum licenses would most likely have run out by 2025 and consequently, there would be no additional costs specifically from the reallocation as they would have had to incur another cost at that point even in the counterfactual.

3 The NSR reports estimates that Telephony & Carrier applications and Enterprise Data applications (both of which also include mobile backhaul usage) are using approximately 29% and respectively 21% of C-band satellite capacity in the MENA region in 2014.

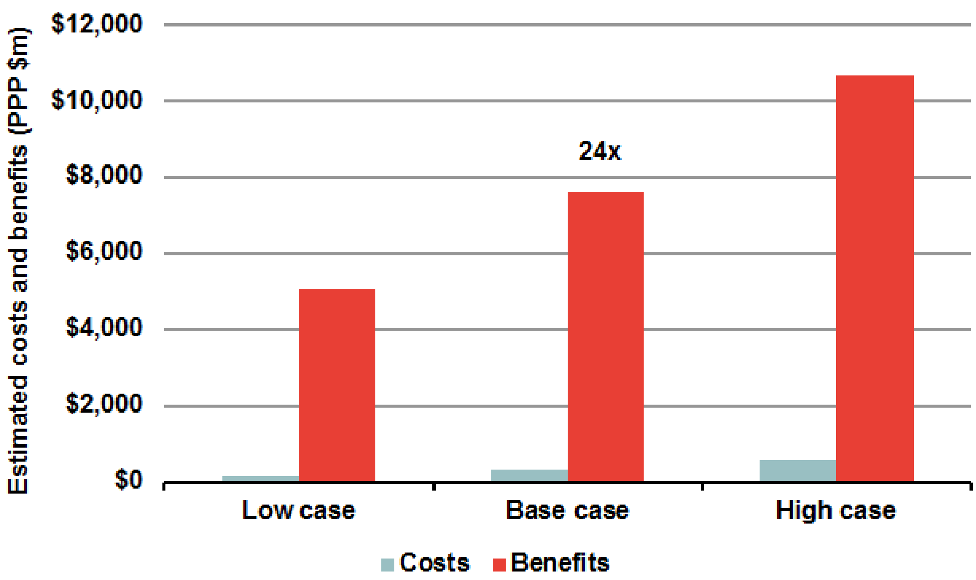
Summary of results

The costs of reallocating spectrum to mobile use would be would be one-off costs to satellite operators. This would be compared with the cumulative value of economic benefits derived from C-band spectrum by mobile operators in the Arab countries.[4]

We have estimated the benefits and costs in the Arab States under three separate benefit scenarios and three separate cost scenarios. The benefits range from approximately PPP US$5 billion to PPP US$11 billion, while costs are estimated between PPP US$0.1 billion and PPP US$0.6 billion.

Figure 1 compares the costs and benefits under low, base and high cases. The benefits exceed costs by approximately **24 times** when comparing the base case for costs with the base case for benefits.

Figure 1. Costs and benefits of C-band reallocation in the Arab States region



Source: Frontier Economics estimates

Simply for representation, we have compared costs with benefits in like-for-like cases. Even when comparing costs in the high case with the benefits in the low case, benefits exceed costs by approximately 9 times.

Our high-level estimate of revenue to the governments in the Arab States through taxation and the auction of licences is over **PPPUS $7 billion.**[5]

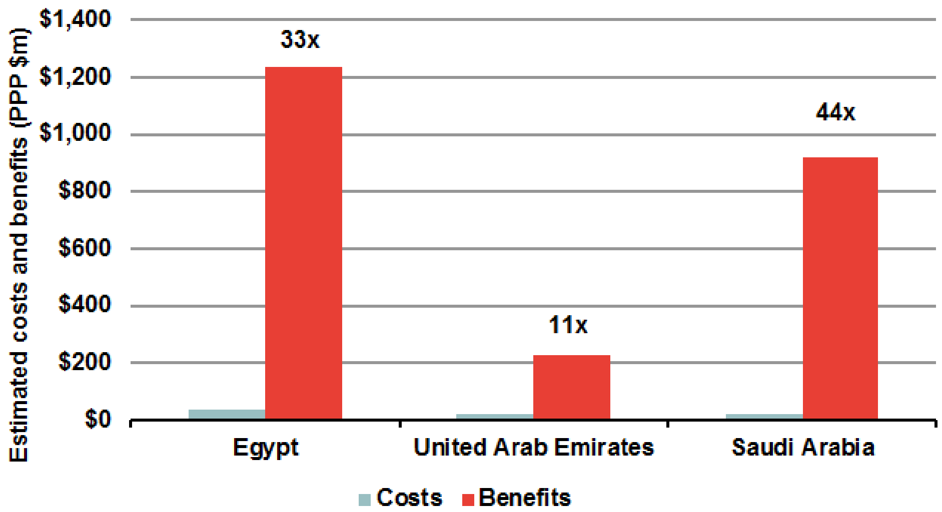
4 The benefits are thus the Net Present Value (NPV) of the profits generated from the use of C-band spectrum by mobile operators over the lifetime of the licence, which is assumed to be 15 years. We assume that the spectrum reallocation will take place in 2025. The one-off costs in 2025 are therefore compared with the NPV of benefits generated between 2025 and 2040. Details on the methodology are provided in Section 3.

We estimate the net benefits of reallocation for the Arab States by extrapolating the estimated benefits and costs in three 'case study' countries: Egypt, UAE and Saudi Arabia.

Egypt is representative of countries where C-band spectrum would be intensively used for mobile in densely populated urban areas. UAE and Saudi Arabia are representatives of countries where mobile broadband penetration is high and data usage has positive projections. For instance, Cisco estimates that mobile data traffic per user in Saudi Arabia will reach 6.43 GB per month by 2018, up from 703 MB per month in 2013. Cisco further predicts that total Internet video traffic (business and consumer, combined) will be 80% of all Internet traffic in Saudi Arabia in 2018, up from 58% in 2013. In 2018, the gigabyte equivalent of all movies ever made will cross Saudi Arabia's IP networks every 7 hours.

Figure 2 compares the costs in the base case with the benefits in the base case for the UAE, Saudi Arabia and Egypt.

Figure 2. Comparing costs and benefits in the base case for case-study countries



Source: Frontier Economics estimates

5 The tax revenue is estimated at a high level by using the average tax rate of the region. The average tax rate is calculated by the World Bank as the ratio of tax revenues to the GDP.

1 Introduction

Consumer demand for data has been increasing in the last decade, and continues to increase. World data traffic has doubled between 2012 and 2013.[6] For the Middle East and Africa in particular, Cisco projects that mobile data traffic will grow 14-fold from 2013 to 2018, representing a compound annual growth rate of 70%.[7] Mobile data traffic is expected to account for 39% of Middle Eastern and African fixed and mobile data traffic by 2018. Furthermore, 90% of mobile data traffic in Africa and the Middle East is projected to be 'smart' traffic by 2018.

While demand continues to increase, on the supply-side, ITU estimates that Region 1 (which includes Europe, the Middle East and Africa) will face a spectrum shortfall of between 779-979 MHz in their "High scenario".[8]

Mobile operators will need to find ways to expand capacity to cater for this demand. While more efficient use of the current spectrum can deliver some of the capacity necessary, the rest will likely need to be delivered through reallocation of spectrum to mobile use. C-band spectrum (3.4-4.2GHz) appears to be well suited to provide additional capacity in urban areas and could help alleviate this expected spectrum scarcity.

The Arab States currently use a significant proportion of C-band spectrum to provide various satellite-based services, including TV distribution. [9] While the principal method of TV distribution in Arab States (direct-to-home) uses Ku-band, terrestrial TV is distributed to broadcast towers using C-band. Additionally, mobile operators and TV networks are likely to have earth stations operating in C-band, and these would be used as hubs for TV contribution and distribution, and global connectivity.[10]

As mentioned earlier, we only assume that a proportion of C-band currently allocated to satellite use would be shifted to mobile use. Reallocating this portion of C-band spectrum, specifically 400 MHz in the lower half of the C-band, to mobile would involve some costs to satellite operators. These would be one-off costs of reallocation. This would be compared with the cumulative value of economic benefits derived from C-band spectrum by mobile operators in the Arab countries.

As part of the cost-benefit analysis, we therefore estimate the benefits from reallocation as the economic value of C-band spectrum to mobile. The costs are estimated as the costs of co-existence for satellite operators.

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6 Ericsson Mobility Report, June 2013. Available at http://www.ericsson.com/res/docs/2013/ericsson-mobility-report-june-2013.pdf

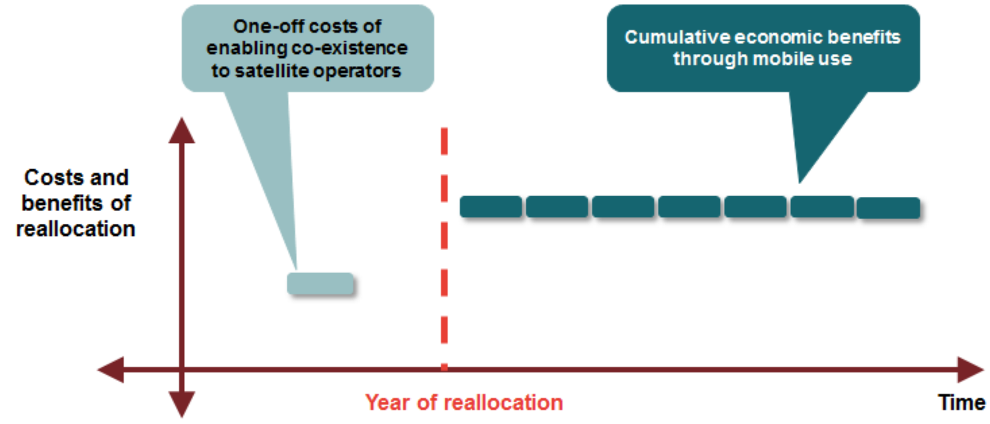
7 VNI Mobile Forecast Highlights, 2013-2018, Cisco. Available at http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country

8 ITU, CPM Report p.21 http://www.itu.int/md/R12-CPM15.02-C-0001/en

9 A part of C-band is used by fixed-wireless operators. We do not explicitly estimate the costs of reallocation to these operators, which we do not expect to be significant.

10 The NSR reports estimates that Telephony & Carrier applications and Enterprise Data applications (both of which also include mobile backhaul usage) are using approximately 29% and respectively 21% of C-band satellite capacity in the MENA region in 2014.

Figure 3. Illustrating our approach



The rest of this report is structured as follows:

- Section 2 provides a summary of the results for our case-study countries as well as for the Arab States region
- Section 3 outlines our methodology behind our results of the costs and benefits of reallocating C-band spectrum.
- Section 4 provides a sensitivity analysis for our results.
- Annexe 1 details the assumptions underlying the estimation of costs and benefits.

2 Summary of results

Our analysis focuses on estimating benefits and costs of C-band reallocation in three 'case study' countries- Egypt, UAE and Saudi Arabia.

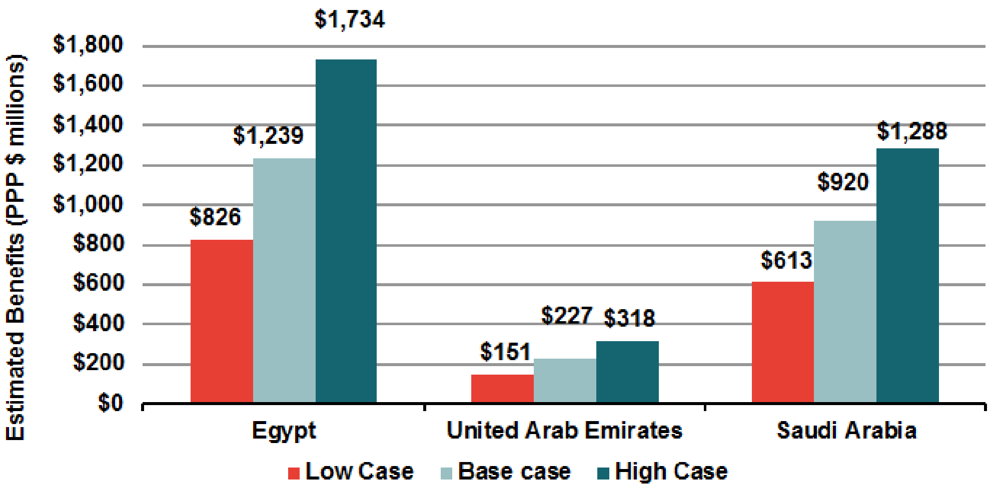
Egypt is representative of countries where C-band spectrum would be valuable in densely populated urban areas, where there would be intense use of spectrum. UAE and Saudi Arabia are representatives of countries where mobile broadband penetration is high and data usage predictions have a firm upwards trajectory. For instance, Cisco estimate that mobile data traffic per user in Saudi Arabia will reach 6.43 GB per month by 2018, up from 703 MB per month in 2013. [11]

Importantly, there is a dramatic shift across the region in the way that news and entertainment content are consumed, with people relying more and more on the Internet to access programming. Cisco predicts that in Saudi Arabia, total Internet video traffic (business and consumer, combined) will be 80% of all Internet traffic in Saudi Arabia in 2018, up from 58% in 2013. In 2018, the gigabyte equivalent of all movies ever made will cross Saudi Arabia's IP networks every 7 hours.

We extrapolate the results from these countries to the rest of the region to assess the costs and benefits of reallocation for the Arab States.

We estimate that reallocating C-band would bring benefits that are **24 times** the costs in the Arab States in our base case. **Figure 4** and **Figure 5** show the estimated benefits and costs in the case-study countries under three separate benefit scenarios and three separate cost scenarios.

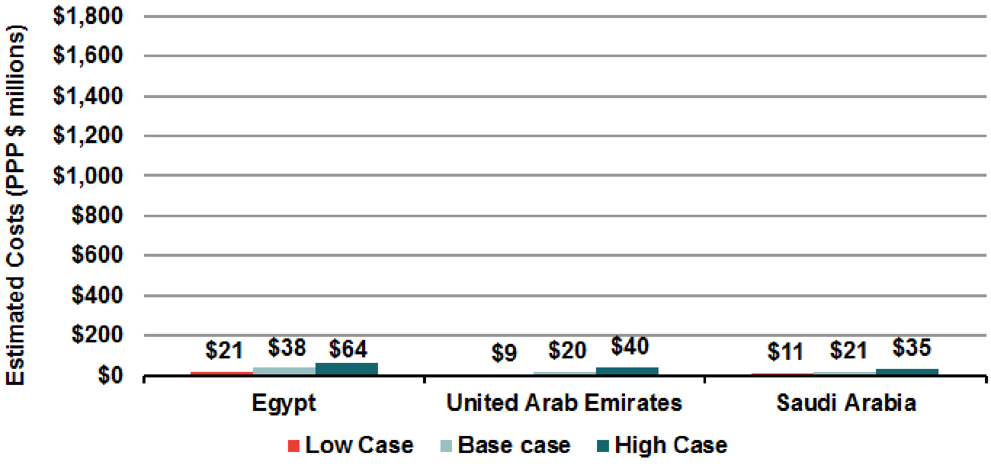
Figure 4. Benefits of C-band reallocation in Egypt, United Arab Emirates and Saudi Arabia



Frontier Economics estimates

[11] VNI Mobile Forecast Highlights, 2013-2018, Cisco. Available at http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country

Figure 5. Costs of C-band reallocation in Egypt, United Arab Emirates and Saudi Arabia



Frontier Economics estimates

For Egypt, the estimated benefits range from PPP US$826 million to PPP US$1,734 million, while costs are estimated to range from PPP US$21 million to PPP US$64 million. In our central base case, the benefits from reallocation outweigh costs by approximately **33 times**. These results are driven by the higher net benefits of reallocation to Egypt because of the high population density. C-band spectrum is ideal for providing capacity to mobile networks in urban areas. The high population density in cities such as Cairo implies that this spectrum would be intensively used, with far more users per cell-site compared to the UAE or Saudi Arabia. This pushes up the benefits from reallocation for Egypt. The costs, while much lower than the benefits, are higher than the other case-study countries because the number of TV viewers increases the costs of reallocation to satellite operators. The high exchange rate in Egypt also increases the real cost of reallocation in PPP terms.

The estimated benefits of reallocation in the UAE range from PPP US$151 million to PPP US$318 million. The costs of reallocation range from PPP US$9 million to PPP US$40 million. The benefits in the base case are **11 times** the costs. The higher benefits are driven by the high GDP/capita which implies higher demand for data and higher willingness to pay for mobile data services. The costs are driven by interference mitigation - the higher urbanisation rate implies most of its terrestrial TV distribution network will be in urban areas, increasing the possibility of interference from mobile when C-band is reallocated.

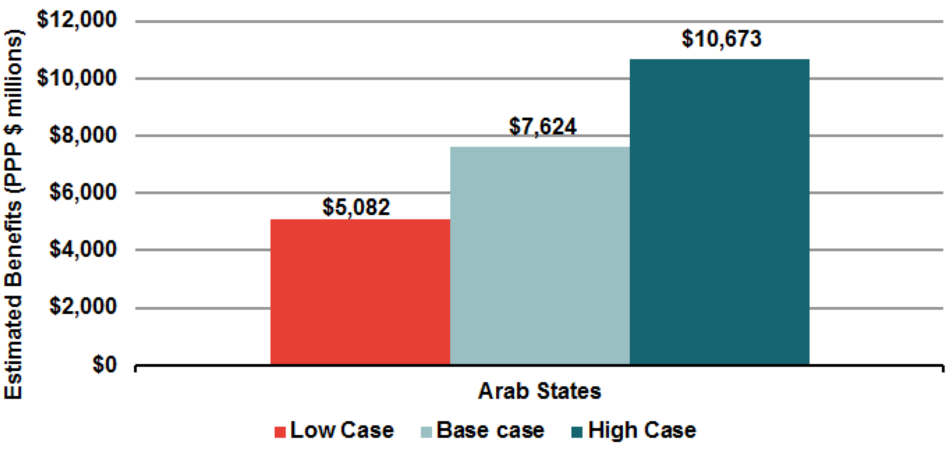
The situation is similar for Saudi Arabia. The benefits range from PPP US$613 million to PPP US$1,288 million while the costs are estimated between PPP US$11 million and PPP US$35 million. The benefits are **44 times** the costs in the base case. The high GDP/capita pushes up the estimate of benefits while costs are driven by interference mitigation.

We break up the Arab States region into two cohorts - the Middle East and North Africa. We use Egypt as a representative for North Africa and the UAE and Saudi Arabia as representatives of the Middle East.

Both benefits and costs are scaled up from case-study countries to the cohorts. Benefits are scaled up using urban population because of the intended urban use of this spectrum. The benefits of this spectrum would thus accrue to the urban populations in these countries and extrapolation based on this measure is most appropriate. Costs are scaled up using population because satellite services are used in both cities and rural areas. Costs and benefits for the two cohorts are added together to estimate the results for the region.

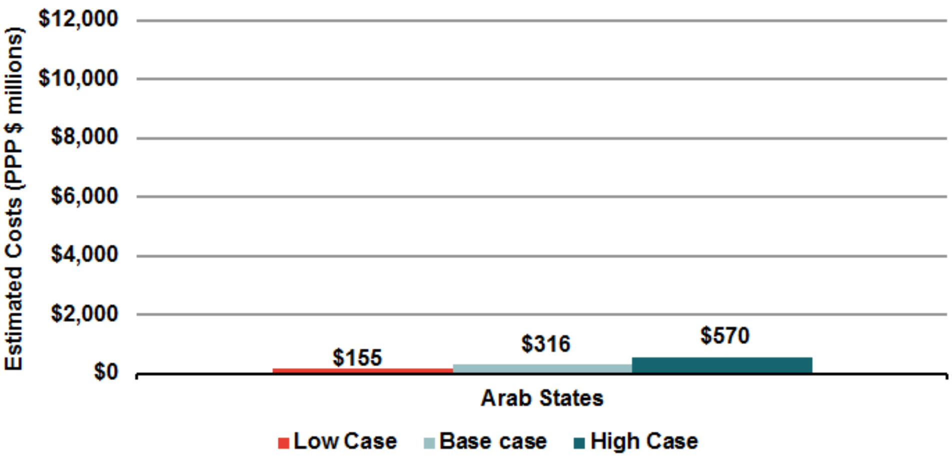
The benefits range from PPP US$5,082 million to PPP US$10,673 million while costs are estimated between PPP US$155 million and PPP US$570 million. In the base case, the benefits exceed costs by approximately **24 times.**

Figure 6. Benefits of C-band reallocation in the Arab States region



Source: Frontier Economics estimates

Figure 7. Costs of C-band reallocation in the Arab States region



Source: Frontier Economics estimates

Based on the estimates of net-benefits of C-band reallocation, we produce high-level estimates of the impact on government income and taxes. We estimate that revenue to the governments in the Arab States through taxation and the auction of licences would be **PPP US$7 billion**.

We outline our methodology for estimating costs and benefits below. We have largely followed the methodology used as part of our previous cost-benefit analysis of reallocation of C-band spectrum in the APAC region.[12] We recognise that there is limited information available about the costs of shifting satellite usage to other frequency ranges. Where information was unavailable, we have quantified costs based on assumptions as per advice from technical experts in the region.

12 "Economic assessment of C-band re-allocation", Frontier Economics, October 2013. Available at www.gsma.com/spectrum/economic-assessment-of-c-band-re-allocation/

Summary of results

3 Estimating the economic impact of reallocation

In this section we outline our methodology in estimating cost and benefits resulting from C-band being reallocated to mobile use in the Arab States region.

3.1 High level description of methodology

As part of the cost-benefit analysis, we estimate the benefits from reallocation as the economic value of C-band spectrum to mobile. The costs are estimated as the costs to the satellite operators of reallocating services to alternate means of delivery.

We assume that only 400 MHz in the lower half of the C-band would be reallocated to mobile. The future demand for satellite services currently provided in C-band would therefore be met through a combination of the remaining 400 MHz of C-band and by moving their operations to alternate frequency bands such as Ka band and Ku band or by migrating to alternative platforms (fixed and terrestrial networks).[13]

By having access to additional C-band spectrum we assume mobile operators will be able to meet mobile data demand and serve future mobile users more efficiently, i.e. at lower costs than in the case without access to C-band spectrum. This is expected to lead to economic benefits (an increase in social welfare) through the following two channels:

- An increase in 'producer surplus' implied by lower costs, i.e. mobile operators will need less resources to meet the future demand for mobile data. It also implies that scarce capital and labour resources in the economy can be freed up and put to other more productive uses.

- If access to C-band spectrum lowers the marginal costs of mobile operators, this would lead to lower prices and higher quantity or quality of services in a competitive market. This would have further positive effects on social welfare.

Figure 8 illustrates a shift in the supply curve, resulting from lower costs from C-band reallocation. This leads to increases in both producer and consumer surplus and thus to an overall increase in social welfare. Furthermore, the relationship between demand and supply in this example leads to lower prices for consumers and higher quantity of mobile data provided.[14]

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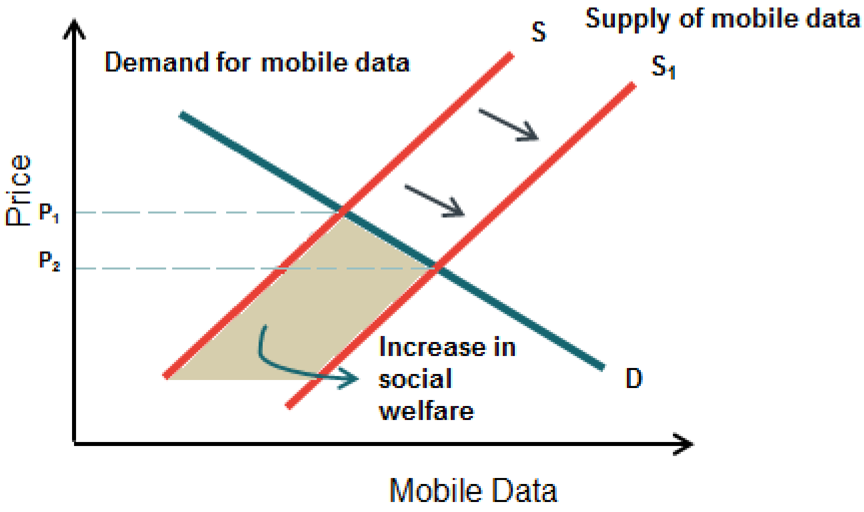
13 We do not explicitly model the cost of satellite operators moving their operations to alternative bands or platforms as we do not expect these costs to be substantial because:

- operations in Ku/Ka band and high-bandwidth operations using terrestrial solutions are typically more cost-effective; and
- satellite operators would have a period of 10 years to move their operations and should therefore be able to do so in the most cost-efficient manner.

14 Since the relative shift in costs and prices will be small, the primary welfare effect is an increase due to the lower costs for mobile operators, some of which will be passed on to consumers

Figure 8. Consumer and producer surplus from C-band reallocation

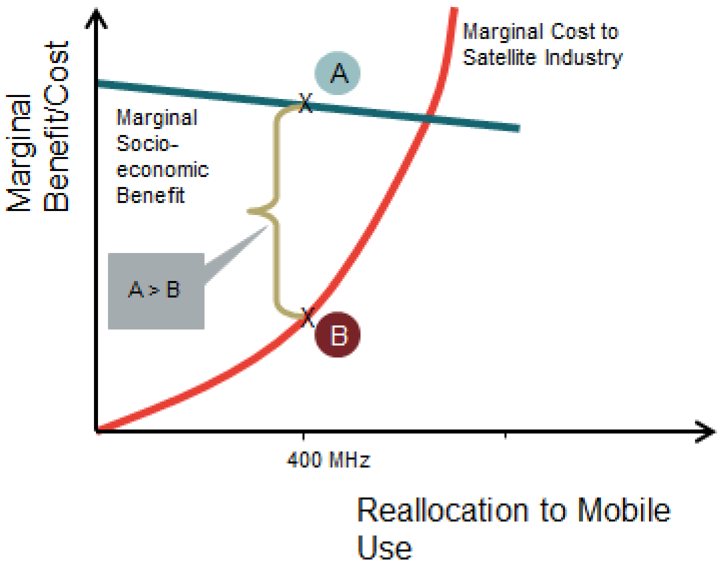


Source: Frontier Economics

At the same time, there are costs that current C-band users would incur as a result of spectrum reallocation. In particular, certain fixed satellite services currently relying on the lower 400 MHz of C-band spectrum would need to be moved to alternate means of delivery, e.g. other frequency bands allocated to satellite or fixed/terrestrial infrastructure. For the satellite applications that will continue to use C-band spectrum after reallocation, there might be costs related to preventing possible interference from mobile networks operating in C-band. Also, there may be additional costs arising from a potential decrease in the quality of services and applications currently using C-band spectrum.

Therefore, our aim is to estimate the incremental benefits of allocating the lower 400 MHz of C-band spectrum to mobile operators and compare that to the costs incurred by the satellite industry. If the benefits are greater than the costs, this would imply that there is an economic rationale for reallocating a share of C-band spectrum as this would lead to an increase in social welfare. **Figure 9** illustrates the point at which the marginal socio-economic benefit from reallocating C-band spectrum to mobile use is greater than the marginal cost to the satellite industry.

Figure 9. Social welfare analysis of C-band reallocation



Source: Frontier Economics

As mentioned, our analysis focuses on estimating benefits and costs of C-band reallocation in three 'case study' countries – Egypt, the United Arab Emirates and Saudi Arabia. Based on the results from these case-study countries, and by using some simplifying assumptions, we also provide indicative results for the Arab States region.

3.2 Estimating the benefits from reallocation

3.2.1 Rationale for the benefits from reallocation

As with the APAC report, we begin by asking two questions regarding the demand and supply situation for spectrum in 2025.

- Will there be need for additional spectrum for the mobile sector?
- If yes, what are the likely benefits to mobile operators from reallocation?

The answer to the first depends on the future levels of demand for mobile services. There is much evidence that there will be a shortfall in the supply of spectrum available for mobile use. The rise in demand for video and data services on mobile devices (such as laptops, tablets and smartphones) will increase the need for additional spectrum.

On the demand-side, Cisco projects that mobile data traffic will grow 14-fold from 2013 to 2018 in the Middle East and Africa, representing a compound annual growth rate of 70%.[15] On the supply-side, ITU estimates that Region 1, which includes Europe, the Middle East and Africa, will face a spectrum shortfall of between 779-979 MHz in their "high scenario".[16]

Despite the estimated short-fall, there are plans for only limited release of spectrum for mobile. It is expected the short-fall will be mostly in urban areas and high frequency spectrum would be best placed to serve this need. Consequently, new spectrum such as C-band is likely to be necessary to meet the needs of urban mobile data users. There are also other ways of meeting the increase in demand:

- **More efficient use of spectrum**

  Advances in technology allow for more efficient use of spectrum by mobile. For instance, Real Wireless estimated that technology developments associated with LTE deployment would provide between a three and ten times increase in mobile capacity for macro cells with three sector antennas by 2030.[17]

- **Increased network deployment**

  Higher traffic demand could be accommodated by increasing the number of sites, that is, by reducing the cell radius. However, as emphasized by UK regulator Ofcom, "there are practical limits on how closely cells can be packed together without causing interference with one another and in securing planning permission for new sites".[18] Also, increasing sites in urban areas would lead to significant deployment cost for operators.

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15 VNI Mobile Forecast Highlights, 2013-2018, Cisco. Available at http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country

16 ITU CPM Report p.21 http://www.itu.int/md/R12-CPM15.02-C-0001/en

17 OFCOM (2012): "Securing long term benefits from scarce spectrum resources: a strategy for UHF bands IV and V", 29 March 2012. Paragraph 3.38.

18 "Securing long term benefits from scarce spectrum resources: a strategy for UHF bands IV and V", Ofcom, 29 march 2012. Available at http://stakeholders.ofcom.org.uk/binaries/consultations/uhf-strategy/summary/spectrum-condoc.pdf

- **Off-loading indoor mobile traffic onto fixed networks**

  This is a viable option in countries where fixed network infrastructure is well developed and has high penetration. It could therefore be an option in the more developed Middle Eastern countries, subject to the availability of WiFi access points and the willingness of mobile users to off-load their mobile traffic. However fixed broadband subscriptions for 2014 were 3% for Arab States, according to the ITU. [19]

However, most studies by national regulatory authorities and international organisations conclude that these methods will not accommodate the significant increases in future demand.[20] Consequently, additional spectrum would be needed to cope with the increasing mobile demand.

As the answer to the first question is that there will be need for additional spectrum by 2025, we estimate the economic benefits of reallocating C-band spectrum to do this.

3.2.2 Methodology to estimate the benefits from reallocation

We assume that C-band will be used to increase capacity of mobile networks in urban areas where demand for mobile data is likely to be high. We therefore assume that C-band spectrum will be used for similar purposes as 2.6 GHz spectrum is currently used in the countries where this high frequency spectrum is available to mobile operators. The first step in estimating the economic benefits of reallocating C-band spectrum therefore is to use the price of 2.6 GHz spectrum as a benchmark. The methodology matches that used in the APAC report and is as follows.

- We estimate the economic value of 2.6 GHz spectrum based on benchmarking of auction prices.[21]
- We then adjust these values to reflect the differences in the value of C-band spectrum compared to 2.6 GHz spectrum.
- Further adjustments were made to reflect country-specific factors, such as the urban population density, 3G penetration rates and ARPU levels.
- From this adjusted price, we then derive the economic value of C-band for our case-study countries and the Arab States region.

ThFigure 10 summarises our methodology.

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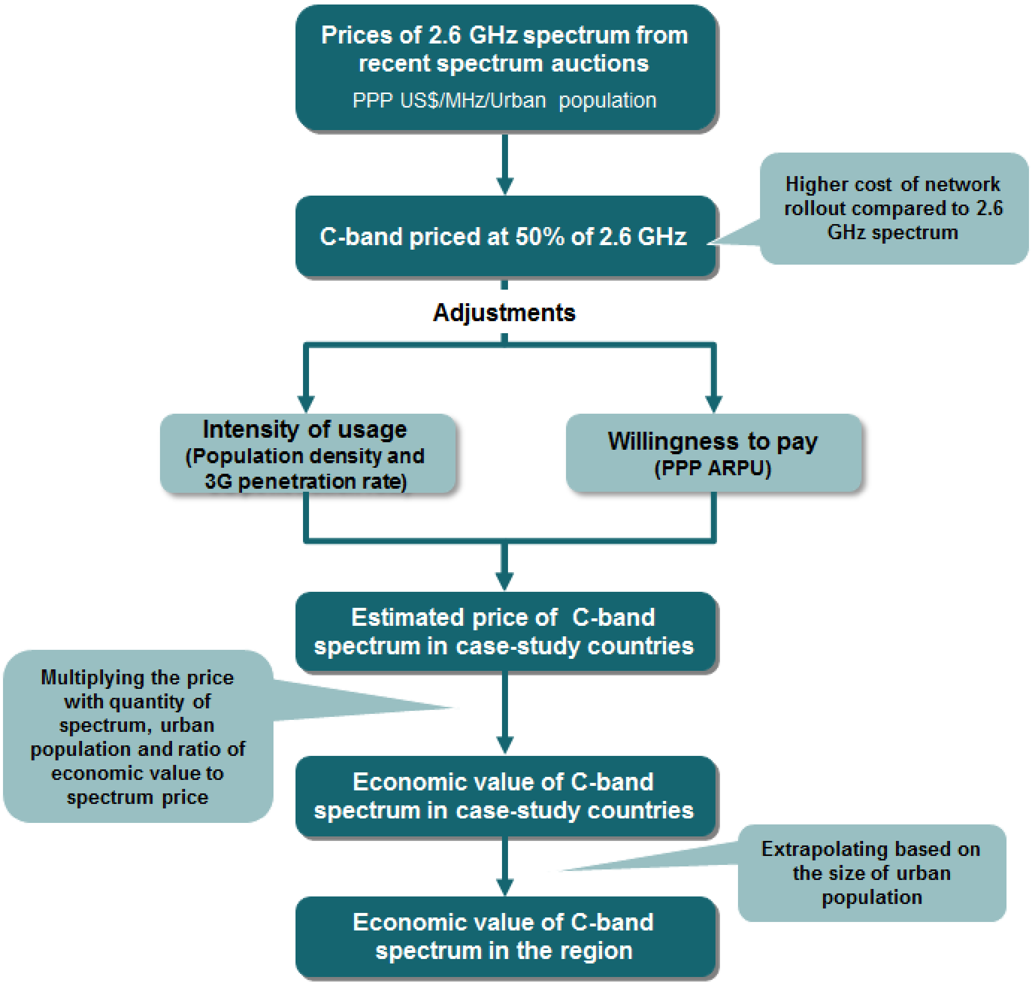
19 http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

20 For instance, "Study of Future Demand for Radio Spectrum in Canada 2011-2015" explicitly takes into account alternative measures to meet spectrum demand, concluding that a substantial spectrum overhead would still be required to meet the expected mobile data demand http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10271.html

21 We have updated our benchmarking analysis to include auctions that have occurred since the time the APAC report was published.

Figure 10. Methodology in estimating benefits



Estimating the value of high frequency spectrum based on auction benchmarking

The future demand and supply of C-band spectrum is uncertain. However, as discussed, it is expected that demand for spectrum for mobile use will exceed future supply. Rather than projecting supply and demand, both highly uncertain, we assume that in 2025 (and beyond), mobile operators will use the C-band spectrum in the same way they are currently using, or planning to use, 2.6 GHz spectrum. Effectively, we assume that the balance between future demand and supply of C-band can be approximated by the balance between the demand and supply for 2.6 GHz. Thus, our starting point is auction benchmarking, which gave a range of prices per MHz/population for the 2.6 GHz spectrum.

We have gathered publicly available data on auctions to benchmark the value of 2.6 GHz from 2009 to 2014.[22] We have also concentrated on auction outcomes for paired spectrum as there is

22 Earlier periods may be less relevant for the purpose of current benchmarking as they pre-date the widespread penetration of smartphones. So, mobile operators may have different valuations of the spectrum, and the period since 2009 coincides with the adoption of LTE as a mobile standard.

Estimating the economic impact of reallocation

less demand for unpaired spectrum, partly due to limited number of devices available for unpaired spectrum. Nevertheless, we assume that this will change and that by 2025 the availability of network equipment and mobile devices will lead to wide use of unpaired spectrum.

To compare different spectrum auctions, we make the following assumptions to "normalise" each observation for consistency.

- all auction prices are expressed as per MHz per urban population to account for the intended urban use of this spectrum;
- we convert all prices to US dollars on a purchasing power parity basis;
- we express prices as 2014 prices by adjusting for CPI inflation since the auction;[23]
- all licence lengths are normalised to a fifteen-year term, using an assumed discount rate.[24]

We then use the median price paid for 2.6 GHz spectrum from this sample as the benchmark price so as to minimise the impact of extreme values in the sample.[25]

Adjusting for the differences in the physical characteristics of C-band

While we have a benchmark price for 2.6 GHz spectrum based on the auction sample, we need to use this to estimate the likely price for C-band spectrum. For this, we use the relative value of C-band spectrum compared to 2.6 GHz spectrum.

The value of C-band is likely to be lower than 2.6 GHz spectrum for two reasons:

1. Difference in physical characteristics

   C-band spectrum is at a higher frequency and so, offers lower coverage (both outdoors and indoors) than 2.6 GHz spectrum. The lower coverage means that a mobile operator would need more cell-sites for a given level of demand. This increases the costs of roll-out (or reduces the benefits) and leads to C-band being valued less than 2.6 GHz spectrum.

2. Lower incremental value of C-band given that 2.6 GHz is already in use

   When the 2.6 GHz spectrum was auctioned, mobile operators in the auction sample were facing relative spectrum supply shortage to provide capacity for their LTE networks. Consequently, they may have placed a high value on 2.6 GHz spectrum. Having won some of this spectrum, it is possible that the value placed on similar high-frequency spectrum will be lower in the years immediately following the sale of 2.6 GHz spectrum.

However, the situation in the Arab States now is different to those in the auction sample. 2.6 GHz has not been used by operators to roll out next generation networks. For Saudi Arabia in

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23 Please note that throughout this report, all our results are presented in US dollar PPP prices for 2013.

24 We estimate prices of a notional fifteen year licence assuming that operators would be indifferent between choosing the fifteen year licence term and the observed licence term given an assumed discount rate.

25 Our auction sample included a wide range of prices, ranging from the Nigerian reserve prices to the price paid in Hong Kong which was much higher than the rest of sample. To control for extreme values, we used the median price of 2.6 GHz as the benchmark.

particular, the lower portion of the 2.6 GHz band is allocated to the Ministry of Defence. The remaining blocks of 2.6 GHz spectrum are unpaired which lowers their value to mobile operators. This limited current use of 2.6 GHz spectrum by mobile operators is likely to increase the demand for C-band spectrum. By 2025, however, it is possible that mobile operators in the Arab States would have also started to use 2.6 GHz. They would therefore also value C-band spectrum less than 2.6 GHz spectrum.[26]

As there have been no auctions for C-band spectrum for mobile, there is no definitive way to estimate the relative value of C-band spectrum compared to 2.6 GHz spectrum.[27] As with the APAC report, we conservatively estimate the value of C-band spectrum to be 50% of the value of 2.6 GHz spectrum in our base case. We include sensitivities around this assumption in our low and high cases. We also model the benefits under an additional scenario where C-band would be worth 20% of the value of 2.6 GHz, as per Ofcom's valuation of the relative values.[28] Even under this scenario, the benefits outweigh the costs by approximately 10 times. Details on this analysis are in Section 4.

Table 1. Value of C-band spectrum relative to 2.6 GHz spectrum

Low Case	Base Case	High Case
40%	50%	60%

Source: Frontier Economics estimates

Applying these relative value estimates to the benchmark price of 2.6 GHz spectrum gives us the benchmark price for C-band spectrum in the auction sample of PPP US$0.03/MHz/urban population. [29]

Adjusting for country-specific differences

We then need to adjust this benchmark price of C-band spectrum to reflect the price that would likely be paid in our case-study countries. Adjustments are made for intensity of usage and willingness to pay assuming a linear relationship between them and spectrum value.[30]

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26 Cisco's projection of data usage in Saudi Arabia in 2018 exceeds the data usage in countries such as the UK, Germany and France in 2013. This demand-side pressure could push up the value of C-band relative to 2.6 GHz. However, we are conservative and ignore this possibility in our estimates for this report.

27 Although Ofcom auctioned C-band spectrum for Fixed Wireless Access (FWA) use in 2003, this is not a relevant benchmark for our estimate. This is because firstly, the demand and supply conditions for FWA would be different to that of mobile and secondly, more recent mobile spectrum auctions are better benchmarks.

28 Variation of UK Broadband's 3.4 GHz Licence, Ofcom, 9 October 2014, Available at http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

29 This estimate is consistent with Ofcom's estimate of C-band value for the UK at PPPUS$ 0.02.MHz/urban population, see "Variation of UK Broadband's 3.4 GHz Licence", Ofcom, 9 October 2014. Available at http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

30 Assuming a linear relationship is consistent with our methodology in the APAC report, as well as the methodology applied by various spectrum benchmarking studies. See for instance DotEcon

Countries with higher levels of total data traffic in urban areas are likely to value C-band spectrum more, all else being equal. This is affected by the following two factors, which we include in our adjustment:

- The number of mobile users served by each base-station - the more the number of subscribers, the more intensively the spectrum will be used. Countries with more densely populated urban areas are likely to have more mobile users for each base-station or cell site. We therefore use the population density in the largest city as a proxy for this; and
- The average amount of traffic per users - the higher the data usage per user, the more valuable the spectrum will be. In general, countries with higher 3G penetration rates are likely to have higher data usage per mobile user. Thus, we use 3G penetration rates as a proxy for traffic per user.[31]

To adjust for differences in willingness to pay and the monetary value of mobile usage, we make use of the PPP Average Revenue per User (ARPU). In general, countries that have higher ARPUs are likely to value data usage and spectrum more.

We therefore estimate the final adjustment factor as follows.

- We first calculate the country's population density, 3G penetration rate and ARPU as a percentage of the auction sample's average population density, 3G penetration rate and ARPU respectively.
- We then take a simple average of these three proportions to obtain the final adjustment factor.

Table 2. Country-specific adjustment factors

	United Arab Emirates	Saudi Arabia	Egypt
Adjustment factor	116%	163%	146%

Source: Frontier Economics estimates

We see that the adjustment factor for all three case-study countries is above 100%. This suggests that C-band would be valued more in these countries than in our auction sample. This is because of slightly different reasons in each country:

- Saudi Arabia and UAE - both have ARPUs almost twice that of the average in the auction sample. The implication is that mobile users in these countries are likely to value data usage more and therefore value the spectrum used to deliver these services more.

study for the Irish regulator available at http://www.comreg.ie/_fileupload/publications/ComReg1071b.pdf

31 This approach is conservative as it is likely to underestimate the willingness to pay in the countries in the Arab States, such as the UAE, where early take-up of 4G services results in lower 3G penetration rates. Thus, given the 4G take-up, it is likely that the willingness to pay in the UAE is higher than the adjustment factor suggests.

- Egypt - Egypt's urban areas are densely populated, 2.35 times that of the average in the auction sample. This means that C-band spectrum would be used intensively to provide capacity to mobile networks in cities such as Cairo and Alexandria, with more users per base-station. This increases the value of C-band in countries such as Egypt.

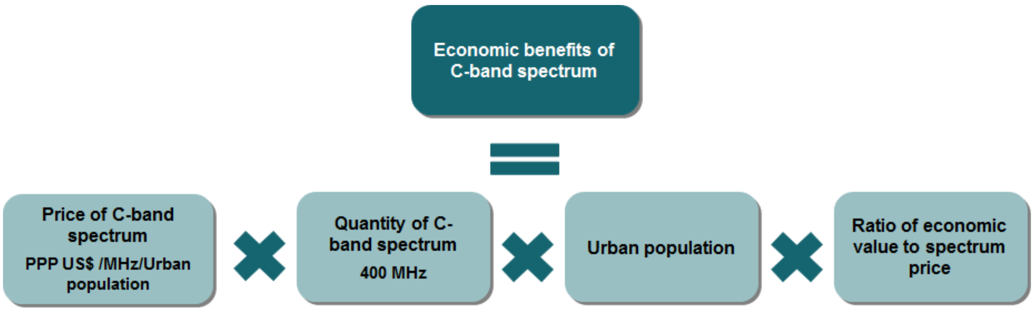
We apply the adjustment factor to the benchmark price for C-band spectrum. This gives us an estimate of the country-specific price of C-band spectrum in PPP US$/MHz/urban population terms.

Calculating the benefits for the case-study countries and the Arab States region

Finally, we derive the economic benefits of C-band for the case-study country by multiplying the country-specific price of C-band spectrum with:

- the amount of spectrum that is assumed will be available (400 MHz);
- the urban populations in each country; and
- the ratio of economic value to spectrum price.

Figure 11. Estimating the economic benefits from C-band spectrum



Our base case assumes the ratio of economic value to spectrum price to be 1.5. We include sensitivities around this assumption in our low and high cases. This is because the spectrum price is based on the winning bid at second-price auctions. This only reveals the willingness to pay of the **second-most efficient operator** participating in the auction, which is directly related to the expected cost savings and so profit increases that this operator can generate from having access to additional spectrum. Therefore, we estimate the full economic value of spectrum or the expected profit of the winning operator as approximately 50% above the price paid in the auction. In other words, we conservatively assume that the winning mobile operator expects to generate profits that are 50% higher than the price they pay for spectrum. [32] This leads to the economic value of spectrum being 1.5 times the price of spectrum.

Benefits, thus calculated, are then scaled up from case-study countries to the cohorts, where Egypt represents North Africa and the UAE and Saudi Arabia represent the Middle East. Benefits are scaled up using urban population because of the intended urban use of this

32 The winner's actual willingness to pay could be considerably more. For instance, bid data released by Ofcom on a recent auction revealed that the winner's willingness to pay was more than twice the amount actually paid, see http://www.bbc.co.uk/news/business-22165797

spectrum. The benefits of this spectrum would thus accrue to the urban populations in these countries and extrapolation based on this measure is most appropriate. The benefits for the two cohorts are added together to estimate the results for the region.

3.3 Estimating the costs of reallocation

To identify the key cost drivers of reallocating C-band spectrum, we first analyse forecast trends shaping the market in the coming years. We find that demand for the satellite-based services typically delivered over C-Band are expected to remain relatively flat in the region. Some applications are also expected to migrate away from C-band onto other technologies, such as fibre cables, Ku-band, High Throughput Satellites (HTS) and Medium Earth Orbit-HTS.[33] In addition to this natural migration, some applications could also be migrated away from C-band in the event of spectrum reallocation because they would be able to function equally well through other technologies.[34] Other applications using C-band may not be able to switch to other technologies because of their requirement for high levels of availability. We assume that the remaining 400 MHz of spectrum after the reallocation would be sufficient to support these applications. Spectrum will be used more efficiently in the future through various technological advances such as MPEG4, HVEC, and the digitalisation of TV transmission.[35]

As a result, the main costs of reallocating spectrum concern the coexistence of these applications in the upper half of C-band alongside the IMT applications using the lower half of C-band, as well as the cost implications for satellite C-band capacity. Our analysis finds three key cost areas:

- writing off satellite capacity;
- resolving interference in TV distribution; and
- resolving interference at urban earth stations.

We explain our method for estimating each of these costs and summarise it in **Figure 12**.

Unlike for the APAC region, we do not find a cost relating to resolving interference in VSAT-based applications.[36] We understand that VSAT terminals primarily use Ku- or Ka-band in Arab States as rain fade is less of a problem than in the APAC region. VSAT terminals would therefore not face interference issues.

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33 The NSR report notes how these technologies will provide competition to C-band and result in migration of demand away from C-band in the Middle East and North Africa.

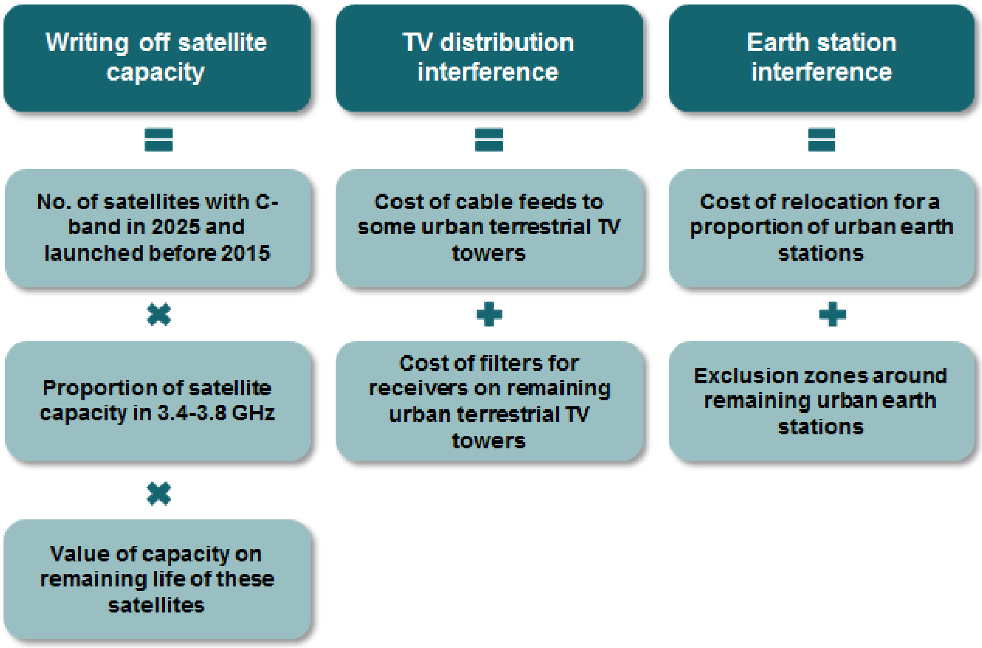
34 We do not expect these costs of migration to be substantial because:

- operations in Ku/Ka band and high-bandwidth operations using terrestrial solutions are typically more cost-effective; and
- satellite operators would have a period of 10 years to move their operations and should therefore be able to do so in the most cost-efficient manner.

35 ITU's "Digital Dividend" report notes the spectrum efficiency of digital transmission compared to analogue (http://www.itu.int/ITU-D/tech/digital_broadcasting/Reports/DigitalDividend.pdf).

36 "Economic assessment of C-band re-allocation", Frontier Economics, October 2013 (herein the "APAC report"). Available at www.gsma.com/spectrum/economic-assessment-of-c-band-re-allocation/

Figure 12. Summary of approach to estimating costs



Writing off satellite capacity

There is some satellite capacity that transmits data through the lower half of C-band which would be made redundant when the spectrum reallocation occurs. The value of this redundant satellite equipment would therefore be a cost of spectrum reallocation. We estimate this as the value of C-band capacity that:

- has been launched before 2015 and will still be operational in 2025; and
- uses the part of C-band that is to be reallocated to IMT.

Underlying our method is the assumption that any satellites launched after a spectrum reallocation announcement would incorporate its implications for future satellite equipment. Therefore, satellites launched between 2015, when the spectrum reallocation would be announced, and 2025, when the spectrum reallocation would take place, face no additional costs through redundant capacity.

We estimate this cost for the Arab States region in three steps:

- **The current number of satellites in the C-band that will still be operational in 2025 -** this is estimated based on current number of satellites carrying C-band to the region and the lifetime of a satellite.

  We understand that satellites with C-band capacity tend to cover both Africa and Arab States simultaneously. Therefore, the 50 satellites providing C-band coverage to Arab States would be indistinguishable from those providing C-band coverage to Sub-Saharan Africa. Since the Arab States' usage of C-band capacity for TV distribution is approximately half of that for Sub-Saharan Africa, we allocate a third of the total number of satellites carrying C-band to Arab States.[37] This provides an estimate that 17 satellites' worth of C-band capacity should be allocated to Arab States.

Similarly to the APAC report, we assume the lifetime of a satellite is 15 years and that satellites have been launched at the same rate over time. This implies that a third of the current satellites in operation in 2015 will still be functioning in 2025, which is when we model the spectrum reallocation to occur. As a result, approximately 6 out of the 17 satellites allocated to this region would still be in operation in 2025.

- **The amount of satellite capacity operating in 3.4-3.8 GHz -** we estimate this based on the proportion of satellite capacity in C-band, and the proportion of that C-band capacity that is within 3.4-3.8 GHz.

  As in the APAC report, we assume the proportion of satellite capacity in C-band is 50%. This reflects how satellite capacity generally consists of C-band as well as Ku- or Ka-band transponders.

  We estimate that one-third of C-band capacity is within the range that would be reallocated. This is because 3.4-3.7 GHz is extended C-band and is not generally used for satellite applications. We understand there is a relatively uniform usage of the remainder of C-band spectrum (3.7-4.2 GHz), implying that a third of C-band capacity would be subject to reallocation.

- **The value of capacity on the remaining life of a satellite -** in estimating this, we consider both the cost of satellite capacity and the average remaining life on the current satellites that will still be in operation in 2025.

  We assume the value of a satellite's capacity to be US$250 million in our central estimate, and provide sensitivities around this for alternative scenarios.

  Of those satellites currently in orbit and which will still be in operation in 2025, we estimate the remaining life to be 2.5 years, which is 17% of their total life span. This is based on our assumption of a 15-year lifespan and the average duration for which they would have already been in orbit.

Using the method shown in **Figure 12**, we combine the key parameters from these three steps to estimate a cost of US$38m for Arab States. This is then allocated to each country in the region based on their expected income per capita in 2025 and the number of households with TVs in 2025 relative to those of the region.[38] Both these factors will determine the value of satellite capacity for a TV broadcaster – the larger and wealthier the TV audience, the greater the value of a TV market. The Arab States already have TV penetration rates above 90%, and we therefore assume all households in the region will have a TV by 2025.[39]

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37 The NSR report estimates the 2013 C-band capacity usage of the Middle East and North Africa for TV distribution as 27.8 TPEs (36 MHz transponder equivalents). The equivalent for Sub-Saharan Africa is 55.9 TPEs.

38 We compare the income per capita of a country to other countries in the region in order to determine how wealthy that country is to the region as a whole. We also compare the number of households with TV in a country to the regional total in order to determine its contribution to the region's TV market. The average of these two factors is used to determine the proportion of the satellite equipment cost that should be allocated to that country.

39 http://wdi.worldbank.org/table/5.12 shows TV penetration rates of over 90% for most countries in the Arab States.

Using this method, we observe that:

- Egypt has the highest share (12%) of the Arab States satellite capacity write-off cost, mainly because of the size of its TV population;
- the UAE and Saudi Arabia have smaller shares of the satellite capacity write-off (6% and 8% respectively) due to their much smaller TV populations. But this is partially offset by their higher income per capita.

Resolving interference in TV distribution

The primary form of TV distribution in the Arab States is direct-to-home satellite TV. However, this is transmitted in Ku-band and therefore there would be no interference issues to resolve.[40] Terrestrial TV, on the other hand, uses C-band to transmit signals to the terrestrial broadcast towers.

We therefore estimate the cost of resolving potential interference issues between terrestrial TV infrastructure and IMT applications using C-band. Given that IMT will be used mainly in urban/suburban areas, this implies there will be no interference to rural terrestrial TV sites. We consider the cost of two solutions:

- providing cable feeds to a proportion of urban terrestrial TV broadcast towers; and
- installing a filter on satellite receivers for the remaining urban terrestrial TV broadcast towers.

We have conservatively assumed that all urban TV broadcast towers will face interference issues, regardless of their specific location. In practice, some broadcast towers in urban areas may not face reallocation costs if, for example, they are positioned at a high altitude and relatively distant from mobile base stations.

We estimate the number of satellite receivers for terrestrial TV in urban areas in each country. This is based on the number of national terrestrial TV networks in a country, the number of satellite receivers per national network, and the country's urbanisation rate. The number of national terrestrial TV networks allows us to account for each national terrestrial TV network requiring its own satellite receivers on a broadcast tower.[41] [42] We also observe that there are 100 broadcast towers used by a national network in Saudi Arabia, and assume the same value for the UAE and Egypt.[43] The country's urbanisation rate is then used as a measure of the proportion of the broadcast towers which are in urban areas. A country with a high urbanisation rate, such as the UAE, is likely to also have a high proportion of its broadcast towers in urban areas.

40 The NSR report shows the 2013 usage of C-band for 'DTH' purposes to be zero in the Middle East and North Africa.

41 Arab Media Outlook 2011-2015, p.141, 168-9 shows the number of terrestrial TV networks in the UAE and Egypt.

42 http://www.bbc.co.uk/news/world-middle-east-14703480 shows there is one state-run terrestrial broadcasting network in Saudi Arabia.

43 Arab Media Outlook 2011-2015, p.159 mentions that 100 broadcasting towers are used for the Saudi Arabian terrestrial TV network. Through the Euroconsult report (http://www.euroconsult-ec.com/news/press-release-33-1/99.html), we also find evidence that this figure applies to Nigeria, a larger and more populated country. Given the limited evidence on the equivalent for UAE and Egypt, we conservatively assume they also use 100 broadcast towers.

Below, we explain our approach for estimating the costs of each solution to the interference issue:

- **Cost of providing cable feeds.** In some urban areas, we acknowledge that the interference from IMT applications could be strong. To resolve this, a proportion of these broadcast towers will require a cable feed. This involves setting up the satellite receiver in an area without interference issues, and then linking it to the broadcast tower using a cable. Our central estimate assumes that 50% of urban broadcast towers will require cable feeds which cost US$100,000 each. We provide sensitivities around both these figures in our alternative scenarios.

- **Cost of installing filters.** For the remaining urban broadcast towers, we estimate the cost of installing a filter to resolve residual interference issues. We use the same cost of a filter as in our APAC report of US$200 and provide sensitivities around it.

Overall, the resulting costs associated with this are:

  - highest for the UAE, where there are two national terrestrial TV networks (as opposed to one in Egypt and Saudi Arabia) and a high urbanisation rate, implying greater amounts of TV distribution infrastructure that would be subject to interference; and

  - lowest for Egypt (before converting into PPP terms), because its urbanisation rate is significantly lower than for the UAE and Saudi Arabia, implying fewer broadcast towers in urban areas.

Resolving interference at urban earth stations

Both mobile operators and TV broadcasters are likely to have earth stations in urban areas for the purposes of global connectivity, TV contribution and TV distribution. We consider two solutions to potential interference issues between these earth stations and IMT applications. These are:

  - relocating the urban earth stations to an area where there would not be interference issues; and

  - implementing a 'mobile-free' exclusion zone around the urban earth stations.

We first estimate the number of urban earth stations within each of our case study countries. This is based on the number of major mobile operators, the number of national terrestrial TV networks, and the number of major cities in each country.[44] We conservatively assume there are two earth stations for each network in each major city and that they all operate using C-band.

Our estimated costs of resolving interference at these earth stations are detailed below:

- **Cost of relocating urban earth stations.** It is likely that interference issues would also be strong between some urban earth stations and IMT applications. We recognise that in these cases, coexistence in the same area may not be possible. Our estimate takes this into account through relocating 50% of the urban earth stations at a cost of US$800,000 each. We provide sensitivities around these two assumptions for our alternative scenarios. In line with the APAC model, we also assume that networks will share earth station facilities – specifically, each urban earth station would support two networks.

[44] We consider major mobile operators to be those with at least 1 million subscribers.

- **Implementing exclusion zones around earth stations.** Based on consultation with a technical expert, it would also be feasible to implement an exclusion zone around some urban earth stations, depending on their specific locations. Interference would be minimised by prohibiting mobile transmissions in a limited area around it, and a study by the GSMA finds that the required size of an exclusion zone is smaller than what has been calculated elsewhere.[45] We assume that the remaining urban earth stations would resolve interference using this solution and that an exclusion zone would carry no cost.

Following this approach, our results show that these costs are:

- the same across all three countries before converting into PPP terms, due to the same number of major cities (2) and same number of combined mobile and terrestrial TV networks (4); and
- highest for Egypt once converted into PPP terms, due to the depreciation of the Egyptian pound in recent years.

The relative contribution of each of these three cost areas to the total costs of each country (in PPP terms) is illustrated in **Figure 13**. It shows the significant impact of the low value of the Egyptian pound on its costs, and that all three cost areas are important to consider.

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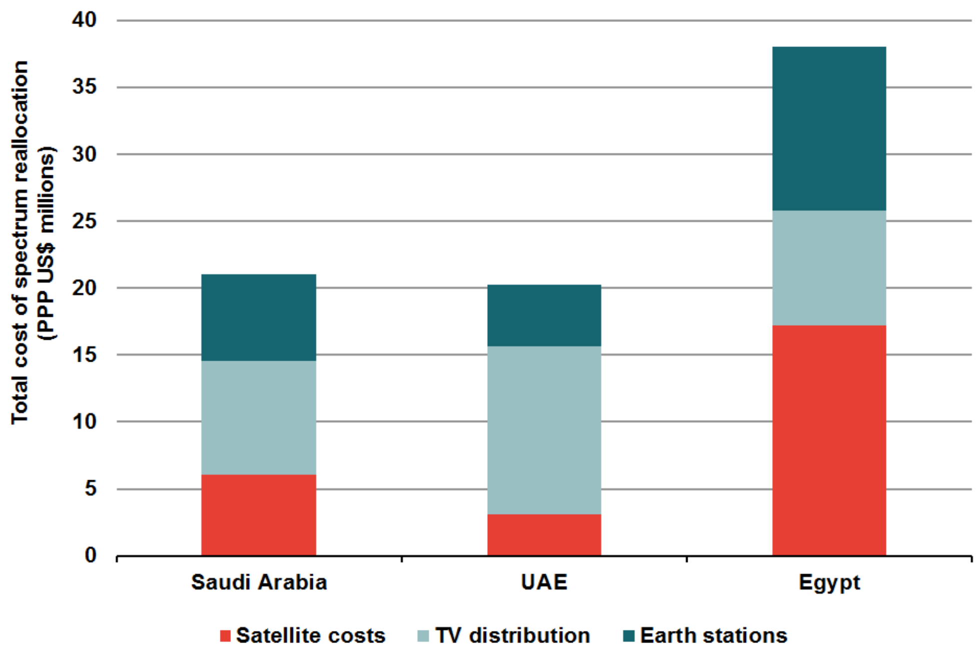
45 The GSMA study, "IMT-FSS Coexistence Scenarios in C-band", finds a separation distance of 2.5-3.5km would be needed between FSS receivers and IMT networks.

http://www.aptsec.org/sites/default/files/2014/06/APG15-3-INF-03_GSMA_AI_1_1_Coexistence_IMT_FSS_on_C-band_31May14.docx

Figure 13. Summary of total cost split by cost type



Source: Frontier Economics estimates

3.4 Estimating the indirect benefits of reallocation

Subtracting the costs from the benefits gives us an estimate of the net benefits as a result of C-band spectrum being reallocated to mobile use.

We conservatively assume that the general economic multiplier is 1. We therefore assume that, as a high-level approximation, the Gross Value Added (GVA) to the economy from the reallocation is broadly comparable with our estimates of the net benefits.

The GVA created from C-band being reallocated will also have an indirect impact in the economy through channels such as additional government income and tax revenue.

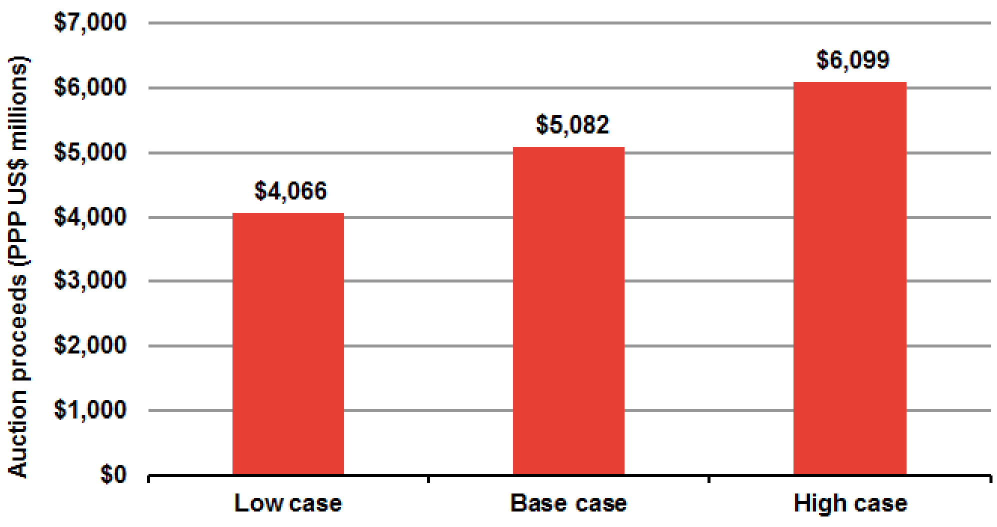
We estimate the impact on government income and tax revenues and address the impact on the wider economy from a qualitative point of view. Our estimates therefore provide a lower bound for the potential benefits that the reallocation of C-band spectrum to the mobile sector can bring to the economy.

3.4.1 Impact on government income

There are two main sources of government income arising from C-band reallocation. The first source is the auction revenues from selling the spectrum licences. The second source is the additional tax income from increased economic activity.

We estimate the overall government proceeds from spectrum licensing by simply multiplying the assumed price of C-band spectrum (per MHz/urban population) by the 400 MHz that is assumed will be reallocated and the total urban population for each case-study country. We then scale the results up for the Arab States region, also based on urban population. We estimate the auction proceeds for the Arab States to be approximately PPP US$5 billion in the base case.

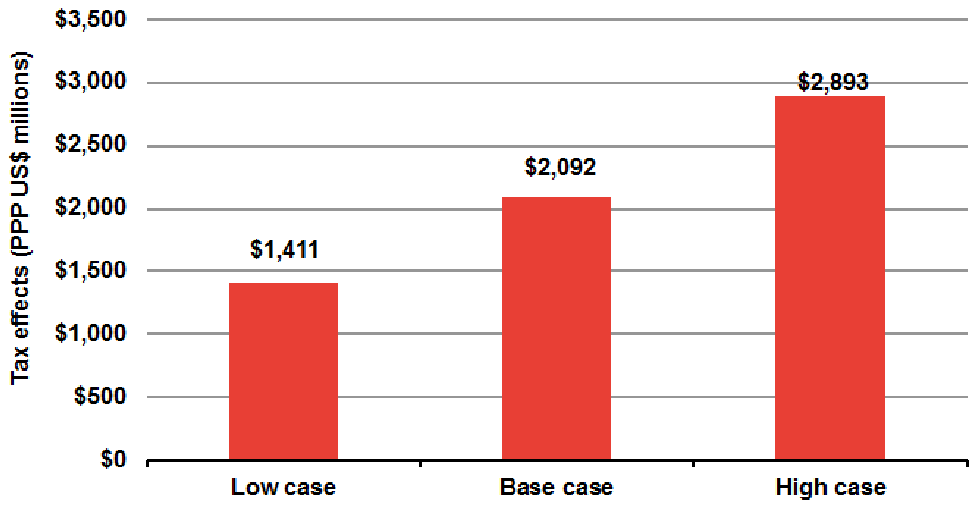
Figure 14. Auction proceeds for the Arab States region



Source: Frontier Economics estimates

The additional taxation revenues will come via direct taxes (such as corporate taxes or income taxes) and indirect taxes (such as value added taxes – VAT). We estimate the tax effects to be approximately PPP US$2 billion in the base-case. In this study we have taken a simple approach to estimating the impact on tax revenues. Hence, our results are only indicative. We apply the average tax rate in Arab States region (total tax revenues as a percentage of GDP) to the estimate of GDP generated from reallocation. They are summarised in **Figure 15**.

Figure 15. Tax effects for the Arab States region



Source: Frontier Economics estimates

The total government income is not additional to the GVA generated as a result of spectrum reallocation. Both the tax revenue and licence fees are transfers to the government.

3.4.2 Impact on wider economy

The reallocation of C-band spectrum to mobile services is likely to exert two additional effects.

- Additional economic activity - the use of C-band spectrum would lead to higher productivity in the mobile sector. This will lead to the mobile sector being able to use fewer resources to produce a given level of output. The freed up resources could then be used by other sectors in the economy to generate economic activity, thereby creating a multiplier effect.

- Higher quality of service for mobile broadband services - by facilitating the flow of information via the use of C-band, improved quality of mobile broadband services encourages the creation of new businesses.

While we recognize the potential importance of these effects, we do not provide a quantitative estimation in our analysis. Hence, our estimation of the benefits from reallocating additional C-band spectrum in the mobile sector should, in this regard, be considered a conservative estimate. We have provided a qualitative assessment of the impact on the wider economy of C-band reallocation in the APAC report, and the same assessment applies for the Arab States as well. We do not repeat that analysis here.

4 Sensitivity analysis

We have estimated the benefits from reallocating C-band to mobile operators to be substantially higher than the costs of the reallocation to satellite operators. These estimates are based on consistently conservative assumptions.

Our results are robust to these assumptions. Even if we were to make unrealistically conservative assumptions, the benefits would outweigh the costs by an order of four.

Specifically, if we alter our assumptions in estimating benefits to the following:

- **The price of C-band spectrum relative to the benchmark price of 2.6 GHz is 20% -** this is based on the implied relative value of Ofcom's estimate of the price for 3.4 GHz compared to the price paid for 2.6 GHz in the UK. [46] The low valuation is likely the result of 2.6 GHz already being in use in the UK to meet the current capacity constraint to a certain extent. The incremental value of C-band spectrum, which would serve a similar purpose, would thus be lower in the years immediately following the sale of 2.6 GHz. This is not likely to be the case for the Arab States because 2.6 GHz is not in widespread-use. This is more likely to mean that C-band would be valued in a similar manner to 2.6 GHz.

- **There are no country-specific adjustments** - this is unrealistic because, as we saw in the previous section, C-band is likely to have a high value because of the intensity with which it will be used in countries such as Egypt, and the higher willingness to pay in countries such as the UAE and Saudi Arabia with high ARPUs.

- **The ratio of economic value to spectrum price is one** - this too is unlikely, especially in light of the bid data revealed by Ofcom after the 4G auctions.[47]

The benefits under these assumptions are still four times the costs under unchanged base case assumptions.

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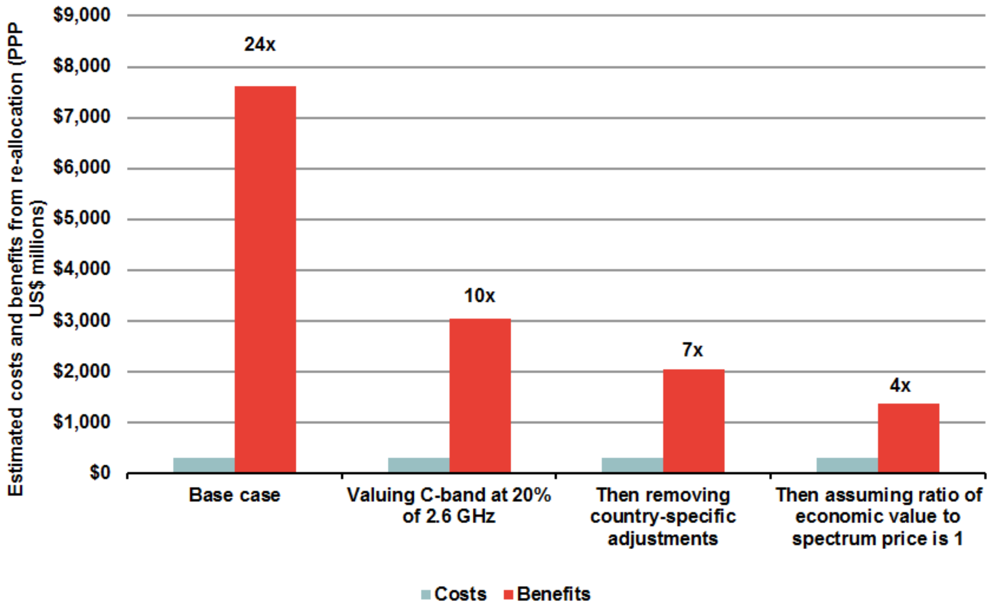
46 Variation of UK Broadband's 3.4 GHz Licence, Ofcom, 9 October 2014, Available at http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

47 The winner's actual willingness to pay could be considerably more. For instance, bid data released by Ofcom on a recent auction revealed that the winner's willingness to pay was more than twice the amount actually paid, see http://www.bbc.co.uk/news/business-22165797

Figure 16. Impact on benefits when changing assumptions



Source: Frontier Economics estimates

In our approach to estimating costs, we mention that we provide sensitivities for certain parameters under alternative scenarios. If we were to apply more conservative assumptions regarding the costs of spectrum reallocation, we would still observe base case benefits that are over 13 times as large as these more conservative costs.

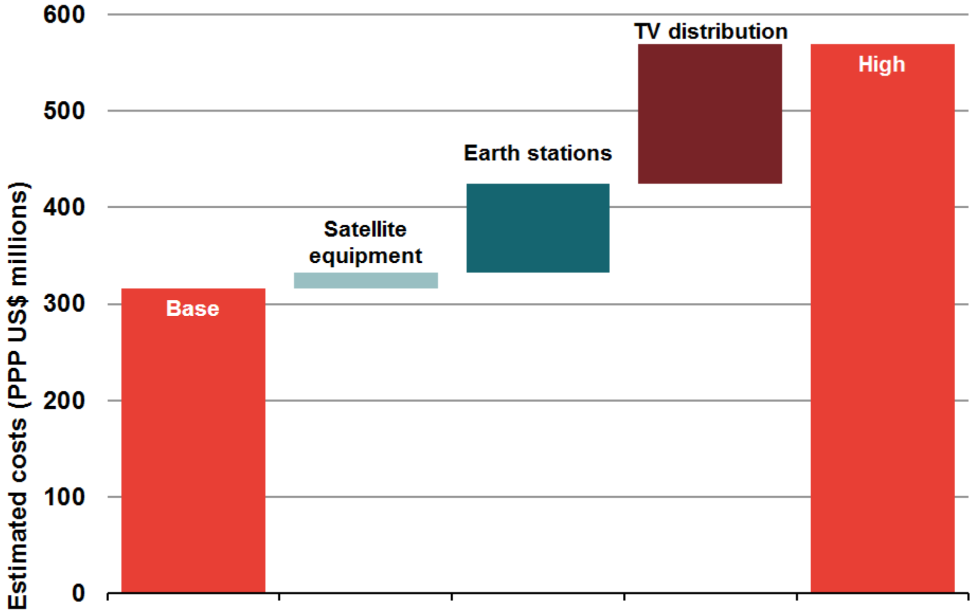
These conservative assumptions consist of:

- increasing the costs of satellite capacity (US$300m), a cable feed (US$125,000), a filter (US$250), and relocating an urban earth station (US$1.1m);
- increasing the number of satellite receivers per national terrestrial TV network (120), and the proportion of urban broadcast towers requiring a cable feed (70%); [48]
- increasing the number of earth stations per network per major city (2.5) and the proportion of urban earth stations to be relocated (60%).

The impact on costs of moving from our base case assumptions to these more conservative equivalents are shown in **Figure 17**. However, they still represent around 7% of the base case benefits for Arab States.

48 We increase the number of satellite receivers per national terrestrial TV network for the UAE and Egypt, but not Saudi Arabia, where we have evidence of this value (as opposed to the assumption used for UAE and Egypt).

Figure 17. Impact on each cost component of movement from base case to high scenario



Source: Frontier Economics estimates

Annexe 1: Detailed assumptions

The tables below summarise the assumptions in the low, base and high cases in estimating the costs and benefits from reallocation.

Table 3. Assumptions made low, base and high cases in estimating benefits

Assumption	Low case	Base case	High Case
Amount of C-band available	400	400	400
Relative price of C-band vs 2.6GHz	40%	50%	60%
Economic value as multiple of spectrum price	1.25	1.5	1.75
General economic multiplier	1	1	1

Table 4. Assumptions made low, base and high cases in estimating costs

Assumption	Low case	Base case	High case
Value of satellite capacity (US$ m)	200	250	300
Terrestrial TV towers per national network	80	100	120
Proportion of urban terrestrial TV towers requiring cable feed	30%	50%	70%
Cost of cable feed (US$)	75,000	100,000	125,000
Cost of filter (US$)	150	200	250
Earth stations per city for each network	1.5	2	2.5
Proportion of earth stations relocated	40%	50%	60%
Cost of relocating an earth station (US$ m)	0.5	0.8	1.1

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