# Economic assessment of C-band reallocation in Africa

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# Executive Summary

Consumer demand for data has increased in the last decade, and continues to increase. World data traffic doubled between 2012 and 2013.[1] For the Middle East and Africa in particular, Cisco projects that mobile data traffic will grow 14-fold from 2013 to 2018, a compound annual growth rate of 70%.[2] Mobile data traffic is expected to be 39% of Middle Eastern and African fixed and mobile data traffic by 2018, compared to 10% in 2013. Furthermore, 90% of mobile data traffic in Africa and the Middle East is projected to be traffic over smartphones by 2018. In sub-Saharan Africa, over half of all subscribers are expected to have 3G connections by 2020, compared to 15% in 2013, which would make it the second largest region for 3G connections by 2020.[3]

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.[4] 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.

Africa uses a significant proportion of C-band spectrum to provide various satellite-based services, including TV distribution.[5] Terrestrial TV is distributed to broadcast towers using C-band. TV networks and mobile operators are likely to have earth stations operating in C-band, and these are used as hubs for TV contribution and distribution, and global connectivity.[6] VSAT-based applications

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

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

3 GSMA "The Mobile Economy: Sub-Saharan Africa 2014". Available at http://ssa.gsmamobileeconomy.com/GSMA_ME_SubSaharanAfrica_Web_Singles.pdf

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

5 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 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.

6 The NSR reports estimates that Telephony & Carrier applications and Enterprise Data applications (both of which also include mobile backhaul usage) are using approximately 14% and 52% respectively of C-band satellite capacity in sub-Saharan Africa in 2014.

also make use of C-band, such as for commercial and public sector connectivity, and mobile backhaul.

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 to the cumulative value of economic benefits derived from C-band spectrum by mobile operators in the African 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 400MHz of C-band, by moving their operations to alternate frequency bands such as Ka band and Ku band or by migrating to alternative platforms.

## Summary of results

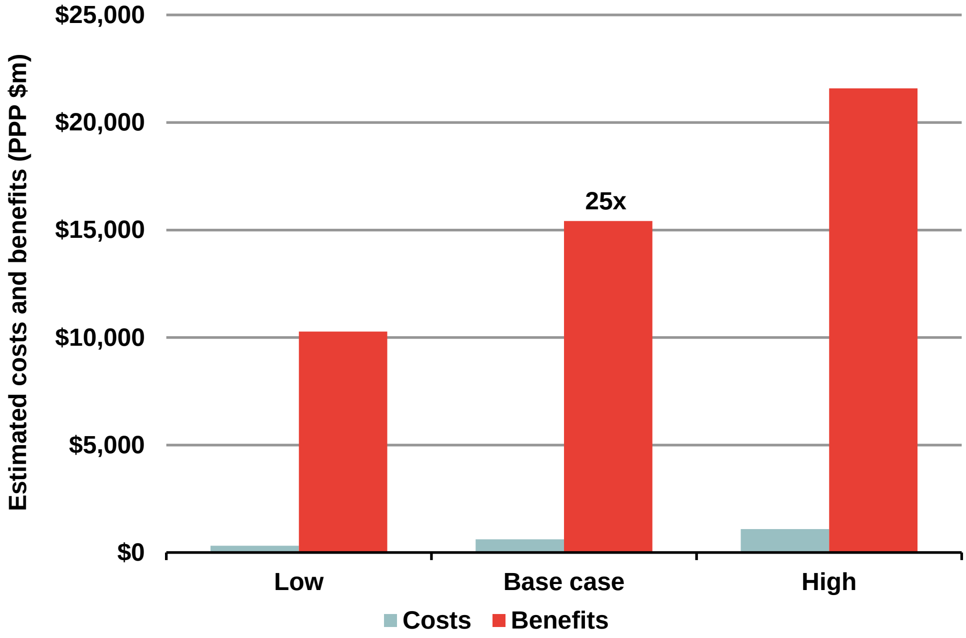
The costs of reallocating spectrum to mobile use would be one-off costs to satellite operators. This would be compared with the cumulative value of economic benefits derived from C-band spectrum by mobile operators in African countries.[7]

We have estimated the benefits and costs in Africa under three separate benefits scenarios and three separate cost scenarios. The benefits range from approximately PPP$10 billion to PPP$22 billion, while costs are estimated between PPP $0.3 billion and PPP $1.1 billion.

**Figure 1** compares the costs and benefits under low, base and high cases. The benefits exceed costs by approximately **25 times** when comparing the base case for costs with the base case for benefits.

[7] 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 license, 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.

**Figure 1.** Costs and benefits of C-band reallocation in Africa




Source: Frontier Economics estimates

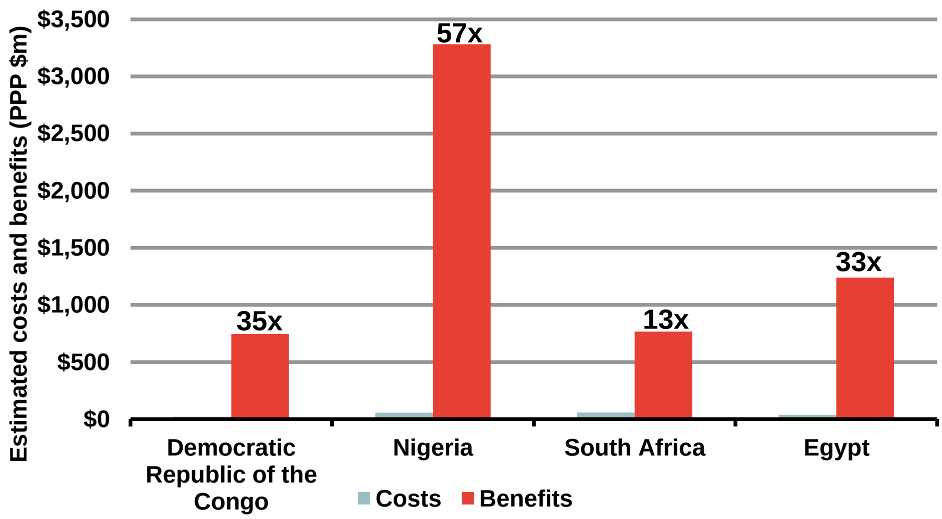
Simply for representation, we have compared base case costs with base case benefits. Even when comparing costs in the high case with the benefits in the low case, benefits are approximately 9 times as large as costs.

Our high-level estimate of revenue to the governments in Africa through taxation and the auction of licenses is over **PPP $13 billion**.[8]

We estimate the indicative net benefits of reallocation for Africa by extrapolating the estimated benefits and costs in four 'case study' countries: Egypt, Nigeria, Democratic Republic of Congo (DRC) and South Africa. **Figure 2** compares the costs in the base case with the benefits in the base case for these four countries.

8 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.

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




Source: Frontier Economics estimates

We recognise that there is a high degree of diversity in Africa, which is difficult to capture precisely using a small number of case studies. Although our case studies may not perfectly represent Africa, these countries capture a reasonable amount of its diversity in terms of how C-band is currently used by satellite industry and how it would be used by IMT (primarily for mobile broadband in urban areas). Egypt is representative of countries with desert climates where C-band spectrum would be valuable for IMT in densely populated urban areas, since there would be intense use of spectrum. South Africa is representative of countries in southern Africa which tend to have higher 3G penetration rates and less densely populated urban areas. Nigeria and the DRC are representatives of tropical countries with densely populated urban areas but with varying levels of 3G penetration.

# 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.[9] 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%.[10] 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”.[11]

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.

Africa uses a significant proportion of C-band spectrum to provide various satellite-based services, including TV distribution.[12] Terrestrial TV is distributed to broadcast towers using C-band. TV networks and mobile operators are likely to have earth stations operating in C-band, and these are used as hubs for TV contribution and distribution, and global connectivity.[13] VSAT-based applications also make use of C-band, such as for commercial and public sector connectivity, and mobile backhaul.

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

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

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

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

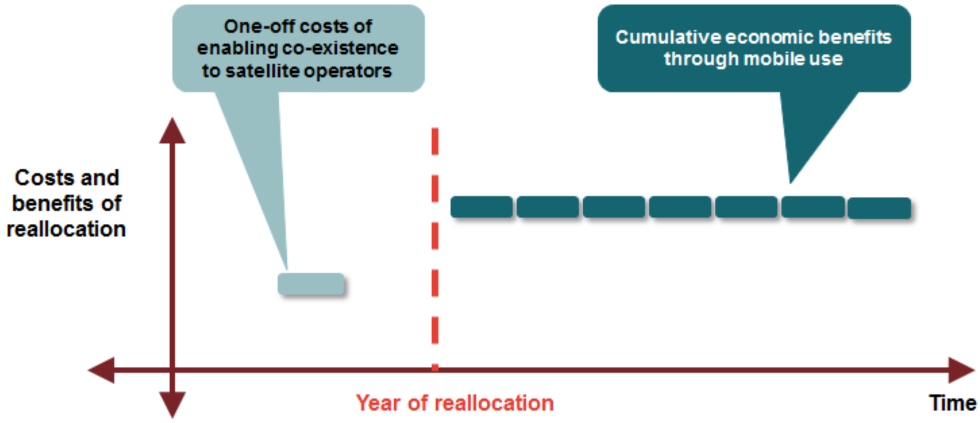
12 A part of C-band is used by fixed-wireless operators. We do not explicitly estimate the costs of reallocation to these operators, which we do not expect to be significant.

13 The NSR reports estimates that Telephony & Carrier applications and Enterprise Data applications (both of which also include mobile backhaul usage) are using approximately 14% and 52% respectively of C-band satellite capacity in sub-Saharan Africa in 2014.

economic benefits derived from C-band spectrum by mobile operators in African 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.

**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 Africa.
- **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

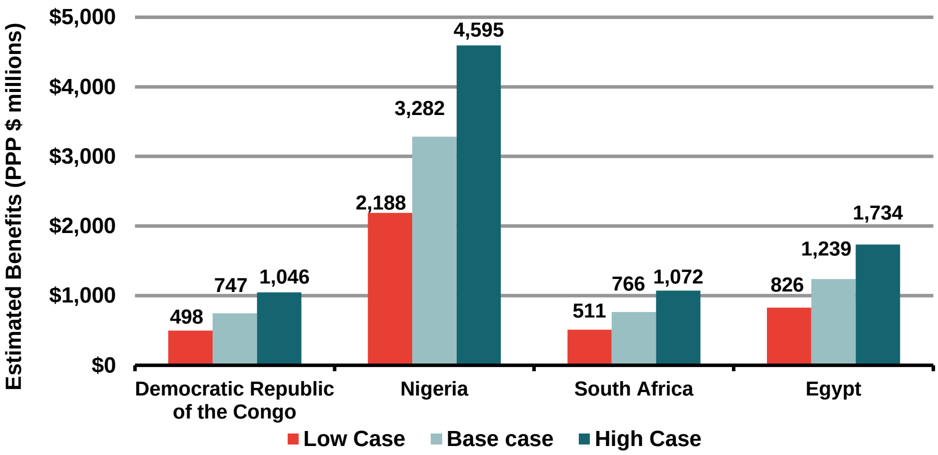
Our analysis focuses on estimating benefits and costs of C-band reallocation in four 'case study' countries – Egypt, Nigeria, Democratic Republic of Congo (DRC) and South Africa.

Egypt is representative of countries with desert climates where C-band spectrum would be valuable in densely populated urban areas, since there would be intense use of spectrum. South Africa is representative of countries in southern Africa which tend to have higher 3G penetration rates and less densely populated urban areas. Nigeria and the DRC are representatives of tropical countries with densely populated urban areas but with varying levels of 3G penetration.

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

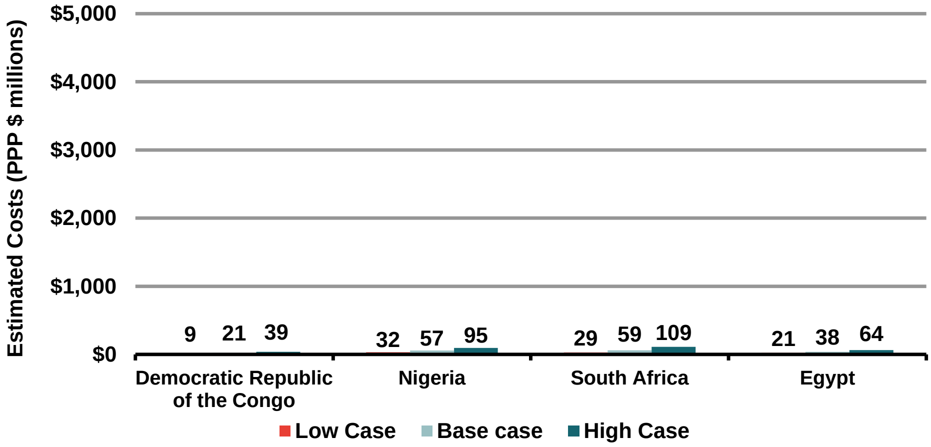
We estimate that reallocating C-band would bring benefits that are **25 times** the costs in Africa in our base case. **Figure 4** and **Figure 5** show the estimated benefits and costs in the case-study countries under three separate benefits scenarios and three separate cost scenarios.

**Figure 4.** Benefits of C-band reallocation in the DRC, Nigeria, South Africa and Egypt




Frontier Economics estimates

**Figure 5.** Costs of C-band reallocation in the DRC, Nigeria, South Africa and Egypt




Frontier Economics estimates

For Egypt, the estimated benefits range from PPP $826 million to PPP $1,734 million, while costs are estimated to range from PPP $21 million to PPP $64 million. In our central estimate (base case), the benefits from reallocation are approximately **33 times** as large as the costs. 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 South Africa. For instance, 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 relative value of its TV market increases the costs of reallocation to satellite operators. The high exchange rate in Egypt also increases the real cost of reallocation in PPP terms.[14]

The estimated benefits of reallocation in South Africa range from PPP $511 million to PPP $1,072 million. The costs of reallocation are estimated to range from PPP $29 million to PPP $109 million. The benefits in the base case are estimated to be approximately **13 times** the base case costs. This is despite the lower urban population density in South Africa, which means that the spectrum would not be used as intensively. The costs are driven by South Africa's higher urbanisation rate, which implies most of its terrestrial TV distribution infrastructure will be in urban areas; and the number of major cities in South

[14] Between 2012 and 2013, the Egyptian pound depreciated by 13% from 6.06EGP/USD to 6.87EGP/USD.

Africa, which implies it has a greater amount of earth station infrastructure in urban areas. Both factors increase the amount of infrastructure for which interference mitigation would be necessary under C-band reallocation.

For Nigeria, the benefits range from PPP $2,188 million to PPP $4,595 million while the costs are estimated between PPP $32 million and PPP $95 million. The benefits are **57 times** the costs in the base case. Similarly to Egypt, the benefits are driven by the high urban population density and large urban population, which means that the spectrum would be intensively used at a given cell-site. The costs for Nigeria are driven by the relative value of its TV market, which increases the cost of reallocation to satellite operators.

The situation is different in the DRC. The benefits range from PPP $498 million to PPP $1,046 million while the costs are estimated between PPP $9 million and PPP $39 million. In the base case, the benefits are approximately **35 times** the costs. The DRC is expected to continue to have a low GDP per capita, which limits the ability of mobile operators to generate value from its customers, other things equal. However, the high urban population density means that urban cell-sites would generate intensive use of spectrum, resulting in greater benefits from reallocation than what the DRC's income alone would indicate. The costs of reallocation are relatively low and driven by interference mitigation, primarily through relocating earth station infrastructure.

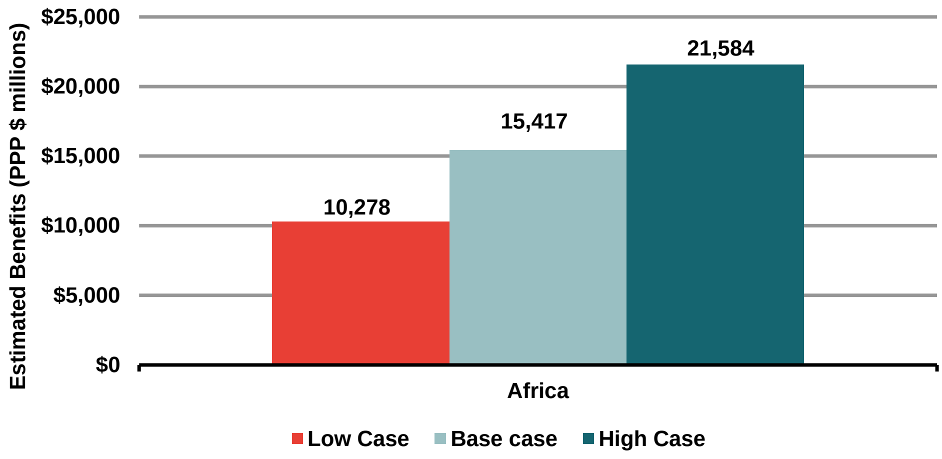
We break up Africa into three cohorts – North Africa, Southern Africa, and the Tropical Africa.[15] We use Egypt as a representative for North Africa, South Africa as a representative of Southern Africa, and Nigeria and the DRC as representatives of Tropical Africa.

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 three cohorts are added together to estimate the results for the region.

The benefits for Africa range from PPP $10,278 million to PPP $21,584 million while costs are estimated between PPP $314 million and PPP $1,095 million. In the base case, the benefits are approximately **25 times** as large as costs.

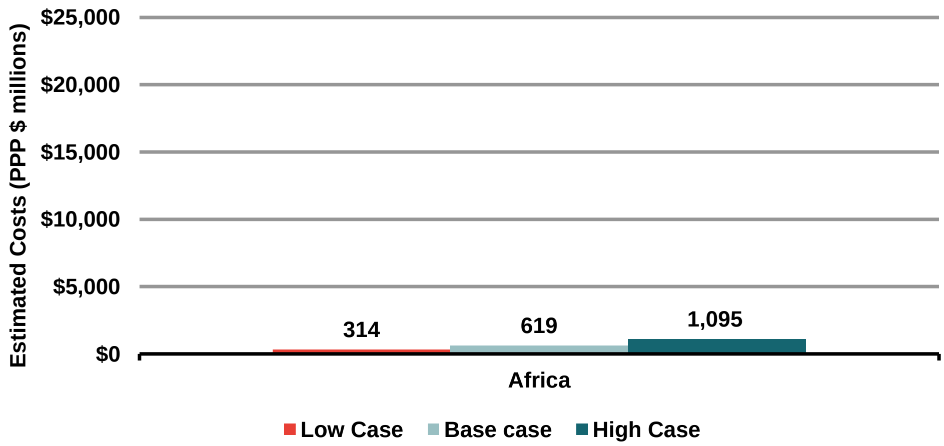
[15] Tropical Africa refers to sub-Saharan African countries that are not part of southern Africa i.e. West Africa, Central Africa, and East Africa.

**Figure 6.** Benefits of C-band reallocation in Africa




Frontier Economics estimates

**Figure 7.** Costs of C-band reallocation in Africa




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 Africa through taxation and the auction of licenses would be over **PPP $13 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.[16] 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.

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

# 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 Africa.

## 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 400MHz of C-band, 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).[17]

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.

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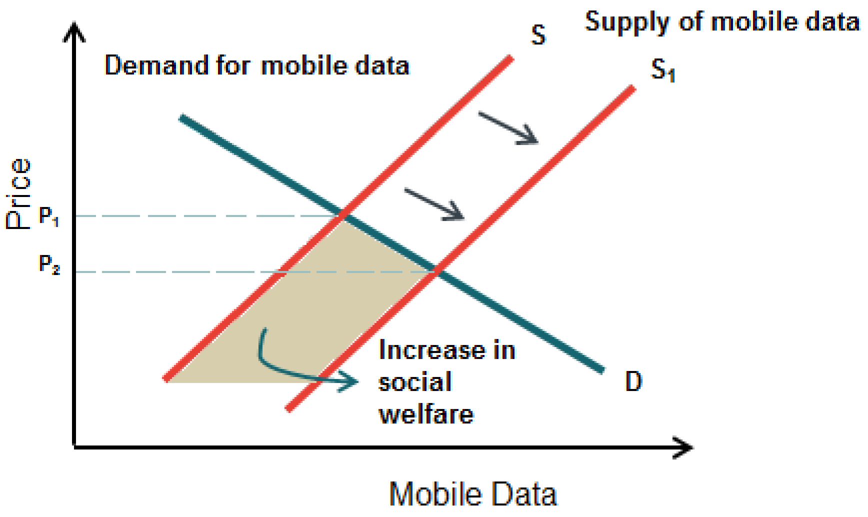
[17] We do not explicitly model the cost of satellite operators moving their operations to alternative bands or platforms as we do not expect these costs to be substantial because:

- 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.

**Figure 8** below 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.[18]

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




Source: Frontier Economics

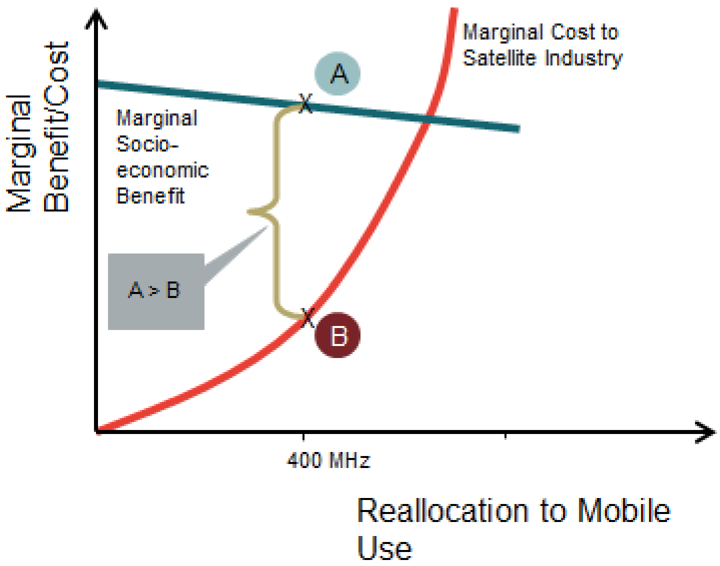
At the same time, there are costs that current C-band users would incur as a result of spectrum reallocation. In particular, certain fixed satellite services currently relying on C-band spectrum would need to be moved to alternate means of delivery, e.g. other frequency bands allocated to satellite or 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 400MHz 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

18 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

spectrum as this would lead to an increase in social welfare. **Figure 9** below 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 four 'case study' countries – Egypt, Nigeria, the DRC and South Africa. Based on the results from these case-study countries, and by using some simplifying assumptions, we also provide indicative results for the benefits and costs to Africa.

## 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%.[19] 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".[20]

Despite the estimated short-fall, there are plans for only limited release of spectrum. It is expected the short-fall will be greatest 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.[21]

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

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

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

- **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".[22] Also, increasing sites in urban areas would lead to significant deployment cost for operators.

- **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 African countries, subject to the availability of WiFi access points and the willingness of mobile users to off-load their mobile traffic. However, it may not be feasible for several African countries where the fixed infrastructure is less developed. However fixed broadband subscriptions were 0.4% for Africa in 2014, according to the ITU. [23]

Most studies by national regulatory authorities and international organisations conclude that these methods will not accommodate the significant increases in future demand.[24] 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

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22 "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

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

24 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

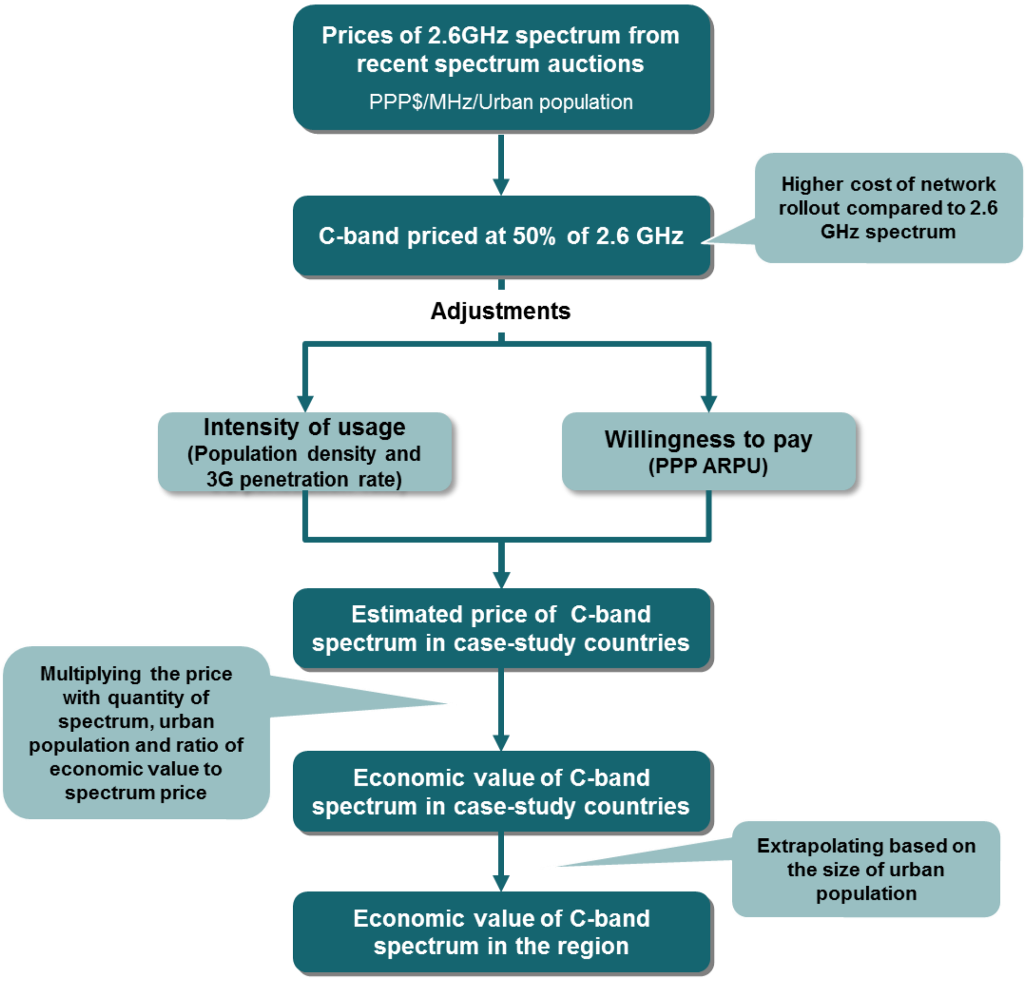
spectrum as a benchmark. The methodology matches that used in the APAC report and is as follows.

- We estimate the economic value of 2.6 GHz spectrum based on benchmarking of auction prices.[25]
- 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 Africa as a region.

The figure below summarises our methodology.

25 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




We now provide details of methodology.

### *Estimating 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.

## Estimating the economic impact of reallocation

We have gathered publicly available data on auctions to benchmark the value of 2.6 GHz from 2009 to 2014.[26] We have also concentrated on auction outcomes for paired spectrum as there is 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;[27]
- all license lengths are normalised to a fifteen-year term, using an assumed discount rate.[28]

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.[29]

### *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

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26 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.

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

28 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.

29 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.

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 Africa now is different to those in the auction sample. 2.6 GHz has not been used by operators to roll out next generation networks. By 2025, however, it is possible that mobile operators in Africa would have also started to use 2.6 GHz. They would therefore also value C-band spectrum less than 2.6 GHz spectrum.[30]

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.[31] As with the APAC report, we conservatively estimate the value 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.[32] Even under this scenario, the benefits are approximately 10 times as large as base case costs. Details on this analysis are in Section 4.

30 Cisco's projection of data usage in South Africa 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.

31 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 in 2003 would be different to that of mobile and secondly, more recent mobile spectrum auctions are better benchmarks.

32 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

**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 $0.03/MHz/Urban population.[33]

### *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.[34]

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.

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,

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33 This estimate is consistent with Ofcom's estimate of C-band value for the UK at PPP$ 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

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

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

| | Egypt | Nigeria | DRC | South Africa |
|---|---|---|---|---|
| **Adjustment factor** | 146% | 127% | 87% | 101% |

Source: Frontier Economics estimates

We see that the adjustment factors for Egypt and Nigeria are above 100%, while it is close to 100% for South Africa and below 100% for the DRC. This suggests that C-band would be valued more in Egypt and Nigeria than in our auction sample. This is because of slightly different reasons in each country:

- Egypt and Nigeria – both have an urban population density over twice that of the average in the auction sample. This means that C-band spectrum will be used intensively to provide capacity to mobile networks in cities such as Cairo and Lagos, with more users per base station.
- South Africa – the urban population density in South Africa is approximately a third of the average of the auction sample, however it has a higher ARPU and 3G penetration rate than the auction sample. This indicates that, although there are fewer urban mobile users served by a given base station, they would value C-band spectrum highly.
- DRC – it has an urban population density almost twice the average in the auction sample, but its ARPU is less than a quarter of the auction sample average and its 3G penetration rate is less than half the auction sample average. Therefore, although its high urban population density suggests C-band spectrum will be used intensively in Kinshasa, this is offset by how much mobile users will value the additional spectrum.

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

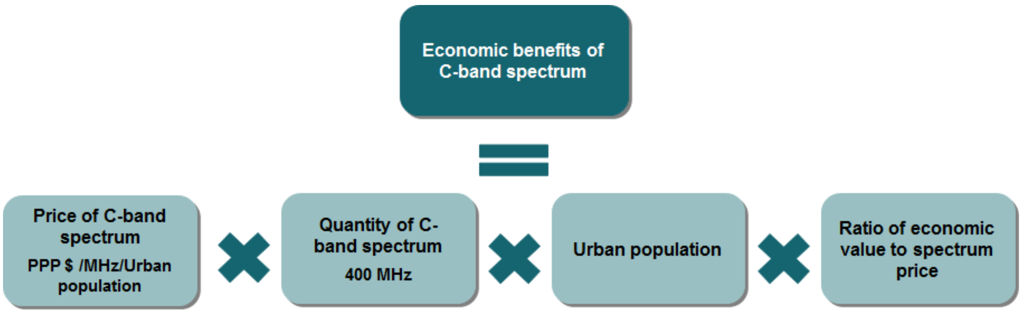
## Estimating the economic impact of reallocation

### *Calculating the benefits for the case-study countries and Africa*

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 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. [35] 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, South Africa represents Southern Africa, and Nigeria and the DRC represent Tropical Africa. 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

35 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

these countries and extrapolation based on this measure is most appropriate. The benefits for the three 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 C-band demand for satellite applications is 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, HTS and MEO-HTS.[36] 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.[37] 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.[38]

As a result, the main costs of reallocating spectrum concern the coexistence of these applications on 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 four key cost areas:

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

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

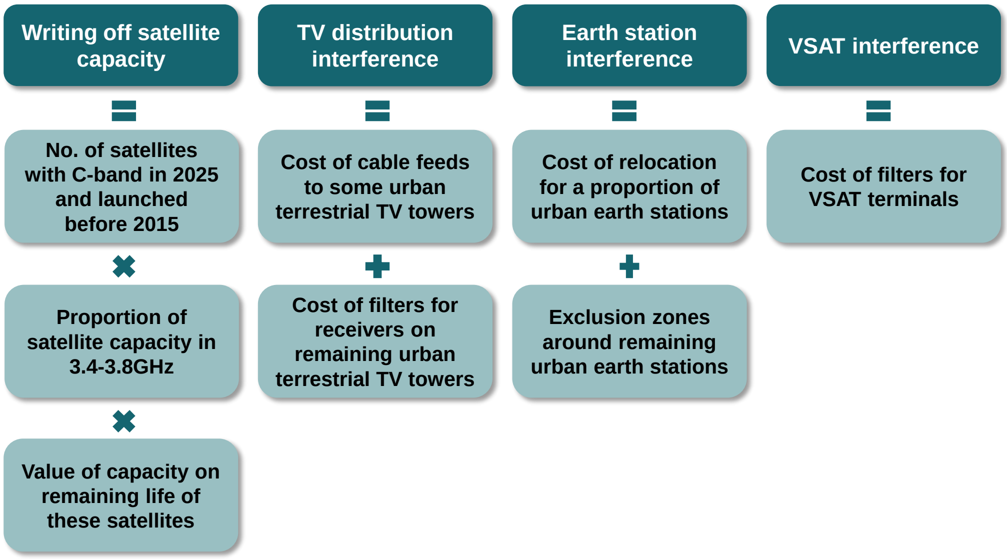
36 The NSR report notes how these technologies will provide competition to C-band and result in migration of demand away from C-band in Sub-Saharan Africa.

37 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.

38 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).

**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 Africa in three steps:

- **The current number of satellites with 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 Sub-Saharan Africa (SSA) and Arab States simultaneously. Therefore, the 50 satellites providing C-band coverage to Africa would be indistinguishable from those providing C-band coverage to the Middle East. Since Sub-Saharan Africa's usage of C-band capacity for TV distribution is approximately twice that for the MENA region, we allocate two-thirds of the total number of satellites carrying C-band to the SSA region.[39] This provides an estimate that approximately 33 satellites' worth of C-band capacity should be allocated to Sub-Saharan Africa.[40]

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 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 11 out of the 33 aforementioned 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 of 3.4-3.8 GHz. This is because 3.4-3.7 GHz is extended C-band and is not generally used for communication satellite applications. We understand there is a relatively uniform usage of the remainder of C-band spectrum (3.7-4.2 GHz), and conservatively assume that approximately a third of used 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$250m 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

39 The report by NSR, "Global Assessment of Satellite Supply & Demand, 10th Edition", estimates the 2013 C-band capacity usage of Sub-Saharan Africa for TV distribution as 55.9 TPEs (36 MHz transponder equivalents). The equivalent for the MENA region is 27.8 TPEs.

40 We use this estimate in obtaining the costs for Sub-Saharan countries. To estimate costs for North Africa, we extrapolate the allocated cost for Egypt estimated for the Arab States report.

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$77m for SSA. This is then allocated to each Sub-Saharan country based on their expected income per capita in 2025 and the number of households with TV in 2025 relative to those of the region.[41] [42] Both these factors will determine the value of satellite capacity for a TV broadcaster – all other things equal, we would expect that the larger and wealthier the TV audience, the greater the value of a TV market.

Using this method, we observe that:

- Nigeria has the highest share (14%) of the SSA satellite capacity write-off cost, mainly because of the size of its TV population;[43]
- South Africa has a relatively large share (10%) due to both its TV population and GDP per capita; and
- the DRC has a small share (2%) due to its smaller TV population and low GDP per capita.

### *Resolving interference in TV distribution*

There are two main forms of TV distribution employed in Africa – terrestrial distribution, primarily free-to-air, and direct-to-home (DTH) satellite distribution, primarily pay-TV. However, DTH distribution in Africa is largely transmitted in Ku-band.[44] We do not consider interference mitigation to DTH subscribers to be a cost driver because there the majority of DTH subscribers have no interference issues to resolve.[45] 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

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41 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.

42 We obtain the forecasted number of TV households in sub-Saharan countries from http://www.theafricareport.com/images/stories/televisiongraph2014.jpg

43 This is similar to Egypt's share of the MENA satellite capacity write-off, which was also driven by the size of its TV population.

44 The Euroconsult report notes that all Pay-DTH platforms use Ku-band capacity and that free-to-air channels distributed for DTH reception often use Ku-band.

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

use 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 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.[46] [47] [48] We observe that there are 100 broadcast towers used by a national network in Nigeria and 65 for the DRC.[49] We assume the equivalent for South Africa is 100 broadcast towers since it is more similar in development to Nigeria. The country's urbanisation rate is then used to estimate the proportion of broadcast towers which are in urban areas. A country with a higher urbanisation rate, such as South Africa, is likely to also have a higher proportion of its broadcast towers in urban areas.

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

- **Cost of providing cable feeds.** We acknowledge that the interference from IMT applications could be strong in some urban areas. To resolve this, a proportion of these broadcast towers would 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

46 "Assessment of C-band Usage In African Countries", Euroconsult shows there are three national terrestrial TV networks in Nigeria (pp. 24-25); and three national terrestrial TV networks in the DRC (p. 42). Available at: http://www.euroconsult-ec.com/news/press-release-33-1/99.html

47 "Mapping Digital Media: South Africa", by the Open Society Foundation shows there are three terrestrial broadcasting networks in South Africa.

48 "Arab Media Outlook", by the Arab Media Forum mentions there is one national terrestrial TV network in Egypt (p.141). Available at: http://www.arabmediaforum.ae/userfiles/EnglishAMO.pdf

49 The Euroconsult report provides evidence of the figures used for Nigeria (p.25) and the DRC (p.41). Available at: http://www.euroconsult-ec.com/news/press-release-33-1/99.html

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 South Africa, which is expected to have the most broadcast towers in urban areas, implying greater amounts of TV distribution infrastructure that would be subject to interference; and
- lowest for Egypt (before converting into PPP terms), because it only has one terrestrial TV network which would face costs from mitigating interference.

### *Resolving interference at urban earth stations*

Both mobile operators and TV broadcasters are likely to have earth stations in major cities 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.[50] We conservatively assume there are two earth stations for each network in each major city and that they all operate using C-band. We provide sensitivities around this estimate in our alternative scenarios.

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. In these cases, coexistence in the same area may not be possible. Our estimate takes this into account through relocating 50% of the

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50 We consider major mobile operators to be those with at least 1 million subscribers.

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.

- **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.[51] 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:

- highest for South Africa, primarily due to the number of major cities which are expected to hold earth stations (4); and
- lowest for Egypt (before converting into PPP terms), due to the smaller number of combined mobile and national terrestrial TV networks (4).

### *Resolving interference in VSAT-based applications*

Some satellite applications rely on VSAT networks to offer connectivity, particularly for users in remote locations. Such networks are used for banking, oil and gas exploration, public sector and mobile backhaul. We consider resolving potential interference issues by installing a filter on all VSAT terminals.

This provides a conservative estimate of the required costs since many VSATs are used in remote locations whereas IMT usage of C-band would be in urban areas. Therefore, not all VSAT terminals would face interference issues in practice. In addition, there is a forecast decline in reliance on VSAT networks in the future due to other technologies, but in our central estimate we assume no migration to other technologies.[52] In our alternative scenarios, we provide sensitivities around the level of migration.

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51 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. Available at: 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

52 The NSR report forecasts "migration to HTS & MEO-HTS capacity to be major negative impact after 2015" on Enterprise Data applications using C-band.

We use estimates of the number of VSAT terminals for Nigeria and the DRC from the Euroconsult report.[53] In the absence of an equivalent for South Africa, we assume the same number as that for Nigeria, since they are relatively similar in development, size and telecoms characteristics. In line with our understanding of the Arab States region, we do not consider such costs to apply to Egypt, since it predominantly uses Ku-band rather than C-band.

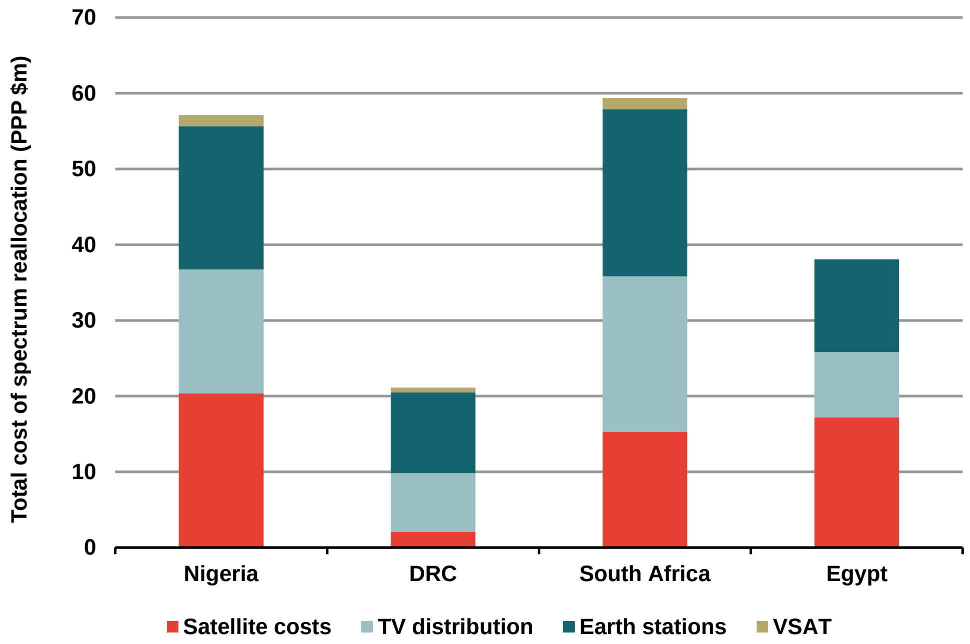
We use the same cost of a filter as in our APAC report of US$200 and provide sensitivities around it. Multiplying this with the number of VSAT terminals provides the cost of mitigating interference in these networks.

The resulting costs are relatively small for the three countries where it applies – all the case study countries have costs below US $1million (before converting into PPP terms).

**Figure 13** summarises the relative contribution of each of the four cost areas to the total costs of each country (in PPP terms). It shows that there are three main cost areas and that the cost drivers can differ across countries.

53 The Euroconsult report states there are around 3,740 VSAT terminals in Nigeria (p.27) and 1,839 in the DRC (p.44). Available at: http://www.euroconsult-ec.com/news/press-release-33-1/99.html

**Figure 13.** Summary of total cost split by cost type




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 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.

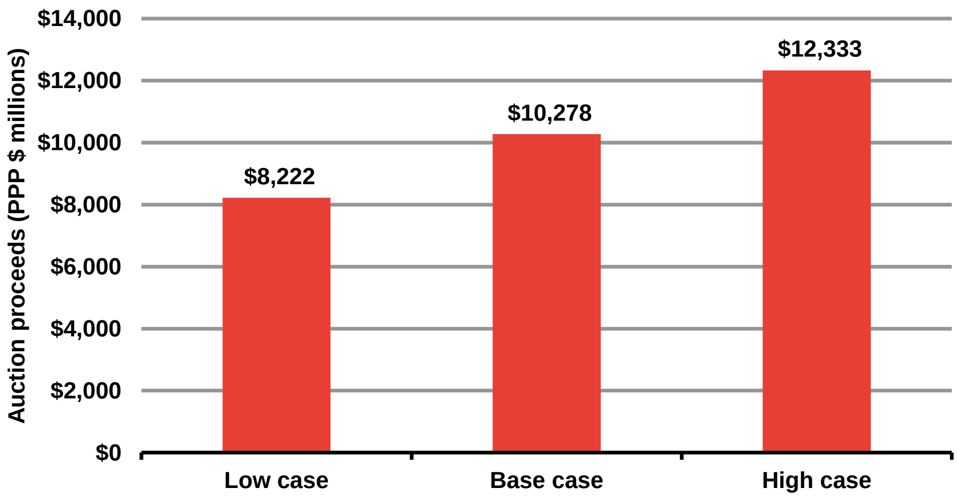
We estimate the impact on government income and tax revenues and address the impact on the wider economy from a qualitative point of view. Our estimates therefore provide a lower bound for the potential benefits that the reallocation of C-band spectrum to the mobile sector can bring to the economy.

### 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 proceeding 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 Africa, also based on urban population. We estimate the auction proceeds for the Africa to be approximately PPP $10 billion in the base case.

**Figure 14.** Auction proceeds for Africa




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 $3 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 Africa (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 Africa


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 license 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 Africa 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 be approximately six times as large as the costs.

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. [54] 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 Africa 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 Nigeria.
- **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.[55]

The benefits under these assumptions are still 6 times the costs under unchanged base case assumptions.

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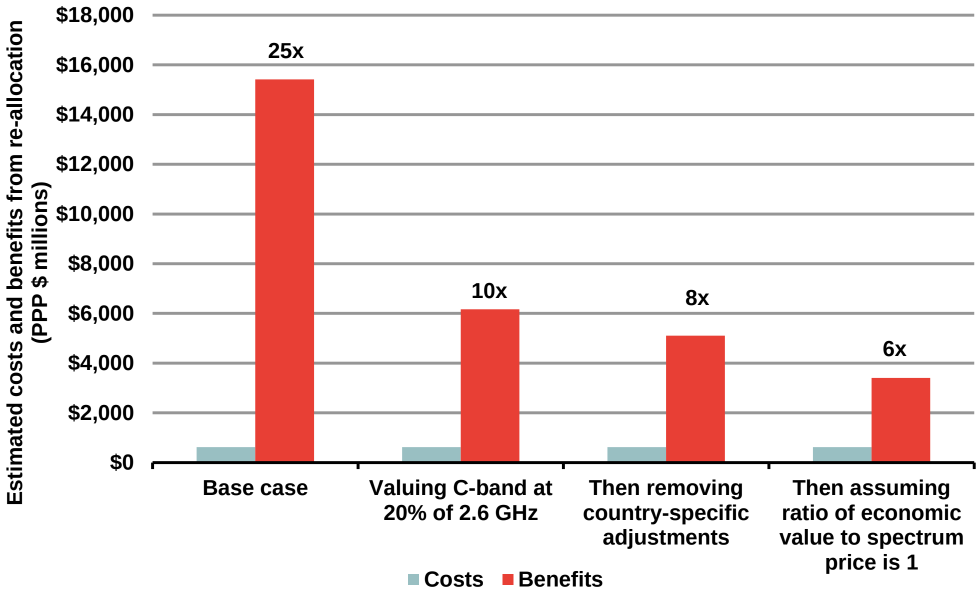
54 Variation of UK Broadband's 3.4 GHz Licence, Ofcom, 9 October 2014, Available at http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

55 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 14 times as large as these more conservative costs.

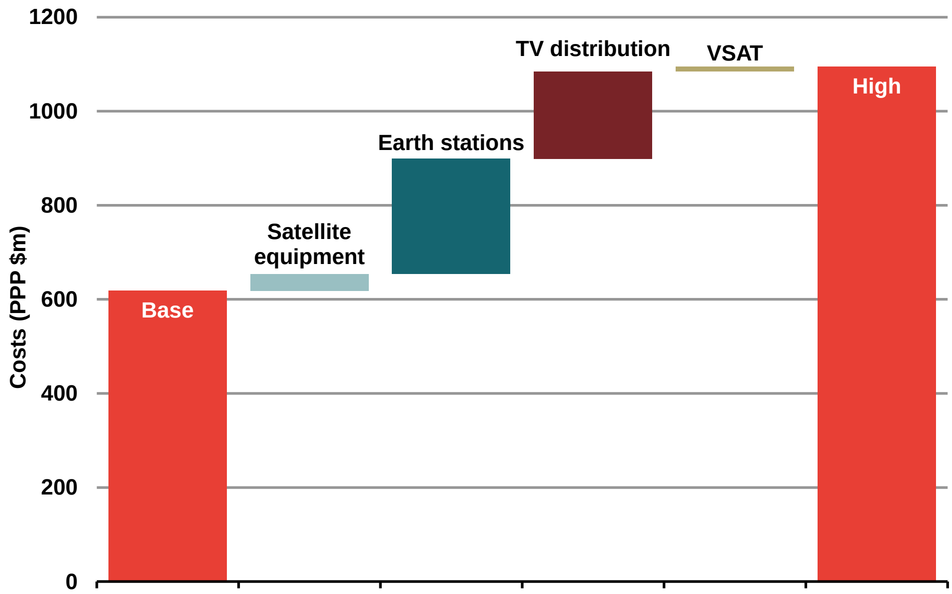
These conservative assumptions consist of:

- increasing the costs (in US$) of satellite capacity ($300m), a cable feed ($125,000), a filter ($250), and relocating an urban earth station ($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%); [56]
- increasing the number of earth stations per network per major city (2.5) and the proportion of urban earth stations to be relocated (60%).

56 We increase the number of satellite receivers per national terrestrial TV network for South Africa and Egypt, but not Nigeria and the DRC. For the latter pair, we have evidence of this value (as opposed to the assumption used for South Africa and Egypt).

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 approximately 7% of the base case benefits for Africa.

**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 2.6** | 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 urban earth stations relocated** | 40% | 50% | 60% |
| **Cost of relocating an earth station (US$ m)** | 0.5 | 0.8 | 1.1 |

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