TELECOM ADVISORY SERVICES

New York - Buenos Aires - Madrid - Bogotá

ASSESSING THE ECONOMIC VALUE OF UNLICENSED USE OF THE 6 GHz SPECTRUM BAND IN BRAZIL

August 2020

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This study was commissioned by the Dynamic Spectrum Alliance and was conducted between May and July of 2020; the authors are solely responsible for its contents.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the support from Richard Bernhardt, National Spectrum Advisor (WISPA); Michael Calabrese, Wireless Future Program and Senior Research Fellow OTI (New America Foundation); Michael Daum, Director, Technology Policy (Microsoft Corporation); Fred Goldstein, Technology Advisor (WISPA); Alex Jucius, Diretor Geral (Associação NEO); Chuck Lukaszewki, Vice-president – Wireless Strategy and Standards (HP Enterprise); Giuseppe Marrara, Head of Government Affairs and Public Policies - Brazil (Cisco Systems); Burhan Masood, Business Development and Product Management - WCC (Broadcom); Louis Peraretz, Vice-president, Policy (WISPA); Chris Szymanski, Director – Product Marketing and Government Affairs (Broadcom), and Ana Luiza Valadares, Head of Public Policy, Connectivity and Access - Brazil (Facebook).

We also thank ABI Research for permission to use their data in this report.

EXECUTIVE SUMMARY

On May 6, 2020, the Board of Directors of ANATEL, the Brazilian regulatory agency, approved changes to its Restricted Radiation Radio Communications ("RRRC") Equipment regulation to allow so-called "unlicensed" operations in the 5.925-7.125 GHz frequency band. Additionally, ANATEL staff was directed to provide the Board with proposed technical rules for RRRC equipment operating throughout this frequency range[1] .

The objective of this study is to provide an assessment of the economic value to be derived by opening the designated band to unlicensed use in Brazil by assessing the impact on service quality, coverage, affordability, as well as focusing on specific applications and use cases likely to be introduced in the enterprise and consumer markets through three classes of 6 GHz devices[2] and favorable technical rules[3].. The methodology relied upon in this study identified the different sources of economic value, estimated them independently and then aggregated within a single value (see table A).

Table A. Sources of Value of 6 GHz Band in Brazil

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhance coverage and improve affordability	Improve affordability associated with broadband provision and increase access sharing in WISP sector		Faster speed of access for WISP subscribers
Increased speed by reducing Wi-Fi congestion	Benefits of eliminating router bottleneck in high speed connections by increasing speed of in-door Wi-Fi		Consumer surplus from increasing speed
Wide deployment of Internet of Things	Spillovers of IoT deployment on productivity of key sectors of the Brazilian economy (e.g. automotive, food processing, logistics, etc.)	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment	
Reduction of enterprise wireless costs		Cost reduction of enterprise use of wireless communications	
Deployment of AR/VR solutions	Spillovers of AR/VR deployment on the Brazilian economy	Margins of ecosystem firms involved in AR/VR deployment	
Enhanced deployment of municipal Wi-Fi	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband

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[1] See https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=06/05/2020&jornal=515&pagina=13.
[2] The three classes of 6 GHz Restricted Radiation Radiocommunications Equipment are low power indoor devices, standard power devices, and very low power devices.
[3] Technical rules such as the amount of spectrum permitted for shared use, radiated power limit, radiated power spectral density limit, and the out-of-band-emissions limit for each class of devices will determine whether the 6 GHz band spectrum can be used to its fullest economic potential.

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Deployment of Free Wi-Fi Hot Spots	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband
Aligning spectrum decision with other advanced economies	Potential opportunity of creating a Wi-Fi equipment manufacturing sector	Benefits of economies of scale of aligning Brazil with US (lower equipment prices)	
Enhancing the capability for cellular off-loading		CAPEX reduction derived from offloading wideband wireless traffic to carrier grade Wi-Fi hot spots	

Source: Telecom Advisory Services analysis

The cumulative economic value between 2020 and 2030 associated with allocating the 1200 MHz in the 6 GHz band amounts to US$ 112.14 billion in GDP contribution, US$ 30.03 billion in producer surplus to Brazilian enterprises, and US$ 21.19 billion in consumer surplus to the Brazilian population (see table B).

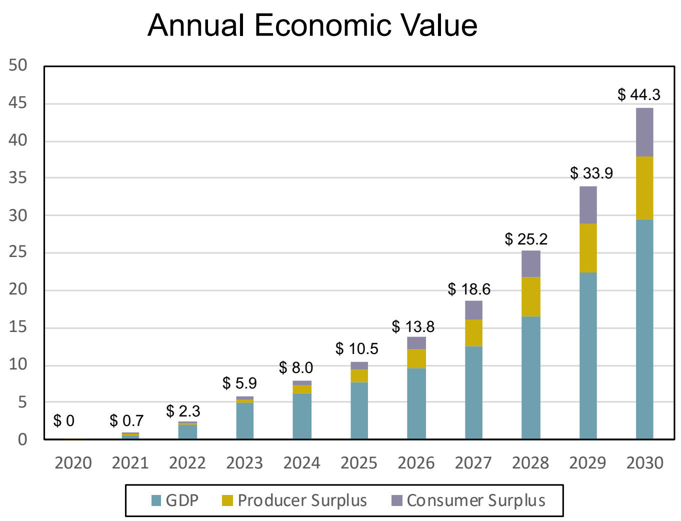
Table B. Brazil: Economic Value of Allocating 1200 MHz in 6 GHz Band (2020-2030) (in US$ billions)

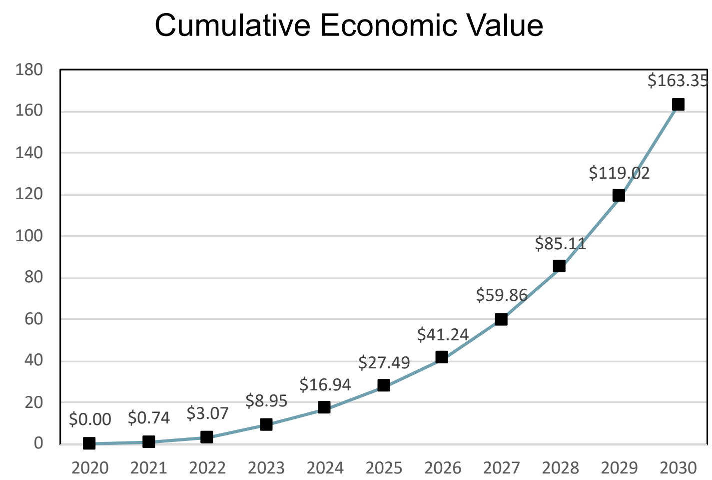
Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhance coverage and improve affordability	**$ 24.91**		**$ 1.21**
Increased speed by reducing Wi-Fi congestion	**$ 27.60**		**$ 16.79**
Wide deployment of Internet of Things	**$ 23.59**	**$ 10.96**	
Reduction of enterprise wireless costs		**$ 8.41**	
Deployment of AR/VR solutions	**$ 29.84**	**$ 10.22**	
Enhanced deployment of municipal Wi-Fi	**$ 4.77**		**$ 0.41**
Deployment of Free Wi-Fi Hot Spots	**$ 1.42**		**$ 2.78**
Aligning spectrum decision with other advanced economies	Potential opportunity of creating a Wi-Fi equipment manufacturing sector (?)	**$0.44**	
Enhancing the capability for cellular off-loading		**$ 8.64** (excluded from total to avoid double counting)	
TOTAL	**$ 112.14**	**$ 30.03**	**$ 21.19**

Source: Telecom Advisory Services analysis

The economic value increases over time with significant acceleration towards the end of the time period due to the value leverage capability of 6 GHz (see graphic C).

Graphic C. Brazil: Economic value of allocating 1200 MHz in the 6 GHz band





Source: Telecom Advisory Services analysis

As stated in this report, the allocation of 1200 MHz in the 6 GHz band for unlicensed use starts yielding economic benefits from day one in terms of addressing Wi-Fi congestion and enabling the development of multiple use cases. The alternative – do not innovate and wait until incumbent telecommunications service providers have a need for additional spectrum – postpones the realization of any economic contribution with the consequent opportunity cost.

1. INTRODUCTION

On May 6, 2020, the Board of Directors of ANATEL, the Brazilian regulatory agency, approved changes to its Restricted Radiation Radio Communications ("RRRC") Equipment regulation to allow so-called "unlicensed" operations in the 5.925-7.125 GHz frequency band. Additionally, ANATEL staff was directed to provide the Board with proposed technical rules for RRRC equipment operating in this frequency range.[4] The regulator is expected to draft rules within 90 days to implement the decision, including applicable power limits and how to protect current spectrum holders from harmful interference for the classes of 6 GHz devices authorized. ANATEL also decided to extend the power limits applicable to short-range devices that operate in the 5150–5350 MHz band, including Wi-Fi routers. The revised rules on RRRE will take effect in September 2020.

The objective of this study is to provide an assessment of the economic value to be derived by opening the 6 GHz band to so-called unlicensed use in Brazil by assessing the impact on service quality, coverage, and affordability, as well as focusing on specific applications and use cases likely to be introduced in the enterprise and consumer markets.

At the aggregate level, the methodology relied upon in this study is similar to the one used in our research in support of the 6 GHz decision in the United States[5], whereby the different sources of economic value were estimated independently and then aggregated within a single value (this allows cumulating GDP impact, with consumer and producer surplus). Along those lines, we proceeded to identify the sources of economic value, estimate their impact, and then combine them.

Chapter 2 provides the background and theoretical framework in support of framing the analyses. Chapter 3 presents the methodologies implemented in order to quantify the economic value to be generated by the proposal under consideration. Following that, Chapters 4 through 12 detail the analyses and results of each source of value. Chapter 13 concludes by proving an aggregate estimate of economic value.

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[4] See https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=06/05/2020&jornal=515&pagina=13.

[5] See Katz, R. (2020). *Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands*. Washington, DC: Wi-Fi Forward.

2. THEORETICAL FRAMEWORK AND BACKGROUND

2.1. The intrinsic value of unlicensed spectrum

Unlicensed spectrum (that is to say, spectrum not owned by a license holder) existed since the 1930s, but in 1985, the United States Federal Communications Commission (FCC) opened up new spectrum for unlicensed use at the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands which led to the introduction of protocols such as Bluetooth and Wi-Fi devices. In 2003, the International Telecommunications Union World Radio-communication Conference, recognizing the growing value of the technology, decided to open more bands to Wi-Fi use around the world. Ever since then, Wi-Fi technology has taken a prominent position in the wireless ecosystem. The success of both standards led to the assignment in the United States of other bands to unlicensed use: at the end of 2008, approximately 955 MHz were allocated to unlicensed use below 6 GHz (the most commonly used bands included 900 MHz, 2.4 GHz, 5.2/5.3/5.8 GHz, and above 60 GHz). In 2014, the FCC assigned the 5.8 GHz band to unlicensed application and is presently considering supplementing this band by making the bottom 45 MHz of the 5.9 GHz band available to unlicensed use. Finally, in 2020, the FCC allocated 1,200 MHz in the 6 GHz band to unlicensed use.

Brazil currently allocates the 2.4 GHz band and parts of the 5 GHz band, roughly 400 MHz in total, for unlicensed use, under technical rules that differ by band. On May 6, 2020, ANATEL approved the unlicensed use of spectrum in the 6 GHz band (5,925–7,125 MHz). In reaching a decision of allocating the 6 GHz band for unlicensed use, ANATEL is evaluating two options: (i) affect the entire 6 GHz band (that is to say 1,200 MHz) for unlicensed use (the model followed by the United States and, potentially, Korea), or (ii) initially allocating 500 MHz (the model initially under consideration by European regulators[6]).

The debate over the most effective way of allocating frequency spectrum has been carried on over the past fifty years, in particular since the publication of Coase's seminal paper (1959) on spectrum management. A seminal issue of the policy debate relates to the management of unlicensed spectrum, which covers the frequency bands for which no exclusive licenses are granted. Key policy questions range from whether granting exclusive licenses would deter innovation to if setting spectrum for unlicensed uses would be costly in terms of reduced government revenues to be derived from auctioning frequency rights. Along these lines, research to date has produced a number of very important contributions in support of unlicensed use (Milgrom et al, 2011; Carter, 2003; Cooper, 2011; Marcus et al, 2013; Crawford, 2011; Benkler, 2012; Calabrese, 2013). That said, while the debate has highlighted the diverse beneficial effects of unlicensed spectrum - such as triggering technological innovation, complementing cellular networks, and the like - research has only recently focused on assessing unlicensed spectrum's economic value, particularly the producer and consumer surplus derived from keeping a portion of the spectrum unassigned

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[6] Because the European countries operate what are considered to be critical services in the upper part of the 6 GHz band, the objective is to show the value of Wi-Fi in the lower part and then investigate the upper part.

as well as its GDP contribution[7]. Part of the difficulty in assessing the value of unlicensed spectrum resides on the fact that, unlike licensed spectrum that is used for a few, homogeneous services, unlicensed bands provide the environment for the provision of several heterogeneous services and devices. Furthermore, given the complementarity between applications relying on unlicensed and licensed spectrum, value estimation of the unlicensed portion is non-trivial. Nevertheless, an evidence-based policy debate requires the rigorous quantification of economic value of the unlicensed spectrum.

In 2009, Richard Thanki produced the first paper to determine the economic value of unlicensed spectrum. He estimated that three major applications (residential Wi-Fi, hospital Wi-Fi, and retail clothing RFID) in the United States generated value in the range of $16 billion to $36.8 billion. At the time, the author acknowledged that these estimates covered only a fraction of the economic value[8] and, consequently, were too conservative. Two years later, Milgrom et al. (2011) supported Thanki's numbers, but also provided additional estimates for other applications. For example, the authors estimated the economic value of Apple's iPad, a device intimately linked to the use of Wi-Fi, at $15 billion. Additionally, the authors quantified other benefits in the United States alone, such as Wi-Fi supported cellular off-loading ($25 billion) and the value of Wi-Fi faster data rates of mobile phones ($ 12 billion). Finally, they referenced other non-quantified benefits, such as the usage of Wi-Fi only devices and future applications such as Super Wi-Fi and Advanced Meter Infrastructure. A year later, Thanki (2012) produced a new piece of research, refining his residential Wi-Fi estimate and quantifying other benefits of unlicensed spectrum. He estimated the annual consumer surplus of residential Wi-Fi to be between $118 and $225 per household (a total of $15.5 billion for the United States). Additionally, enlarging the original scope of benefits, he assessed the producer surplus derived from carrier savings resulting from Wi-Fi off-loading ($8.5 billion for the United States). Finally, he estimated the value generated by enhanced affordability (an assessment mainly focused on emerging markets) and mentioned potential innovation related benefits related to deployment by Wireless Internet Service Providers. In the same year, Cooper (2012) calculated the economic value by estimating the number of cell sites that the wireless industry would avoid investing in as a result of traffic off-loading to Wi-Fi carrier grade hot spots (130,000), which would result in annual savings of $26 billion. Ina similar vein, the author of this paper has developed numerous studies assessing the economic value of unlicensed spectrum for different bands in the United States (Katz, 2014a, 2014b, 2018, 2020) and other advanced economies (Katz et al., 2018).

In all, the evidence is quite compelling about unlicensed spectrum capacity to enable numerous applications, services and devices (see table 2-1):

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[7] This is contrary to research on the valuation of consumer welfare derived from the use of licensed spectrum which has been a fairly standard research practice given the availability of auction data and consumption series (see Hazlett (2005): Hausman, 1997).

[8] Thanki estimated that the three applications represented 15% of the unlicensed wireless chipsets to be shipped in the US in 2014.

Table 2-1. Unlicensed Spectrum: Standards and enabled complementary technologies

Standards	Frequency bands	Geographic Range	Data rate	Devices and applications
Wi-Fi (802.11b, 802.11ax)	• 2.4 GHz • 3.6 GHz • 5 GHz • 6 GHz	• indoor: 38 meters • outdoor: 125 meters	• Up to 1200 Mbps	• Computers, Printers, scanners, tablets • Mobile phones, scanners • AR/VR devices
Bluetooth (802.15.1)	• 2.4 GHz	• Short range indoors	• 1-3 Mbps	• Phone headsets, PC networks • Barcode scanners • Credit card payment machines
ZigBee (802.15.4)	• 915 MHz	• 75 meters	• 250 Kbps	• Wireless light switches • Electrical meters with in-home-displays • Traffic management systems
Wireless HART (802.15.4)	• 2.4 GHz	• indoor: 60 -100 meters • outdoor: 250 meters	• 250 Kbps	• Equipment and process monitoring • Environmental monitoring, energy management • Asset management, predictive maintenance, advanced diagnostics
Wireless HD	• 60 GHz	• 30 feet	• 28 Gbps	• High Definition consumer electronic devices
WiGig (802.11ad)	• 60 GHz	• 5 -10 meters	• 6 Gbps	• Smartphones, Tablets, Docking stations • PCs & Peripherals, TV & Peripherals • Digital Cameras, Camcorders
RFID	• 50-500 KHz • 13.56 MHz • 0.9 to 2.5 GHz	• Up to 29 inches	• Read-only: 8.75 kbps • Active Read - Write: 3 kbps	• Asset tracking • Livestock tracking, credit card payments • Highway toll payments • Supply chain management

Source: Compiled by Telecom Advisory Services

The economic value generated by the use of unlicensed spectrum can be categorized across four dimensions:

- **Complementing wireline and cellular technologies:** A complementary technology is a resource that, due to its intrinsic strengths, compensates for the limitations of another. In the case of spectrum management, unlicensed frequency bands can enhance the effectiveness of devices that use licensed spectrum. For example, Wi-Fi base stations operating in unlicensed bands can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi access points, thereby reducing the cost of broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi site can reduce their costs of access by turning off their wideband service. They can also gain additional access speed because the transfer rate of Wi-Fi sites is generally faster than that offered by cellular technology (although 5G is narrowing down the difference).

  Wireless operators can also reduce their capital spending by complementing their cellular networks with carrier-grade Wi-Fi access points, which are considerably less expensive than cellular network equipment with similar capacity. In addition to reducing spending, wireless carriers can offer fast access service without a base station congestion challenge. Finally, cellular carriers derive benefits from avoiding CAPEX because a portion of traffic is off-loaded to residential Wi-Fi or business networks.

- **Developing alternative technologies, thus expanding consumer choice**: In addition to complementing cellular networks, unlicensed spectrum can provide the environment needed for operating technologies that are substitutes to licensed uses, thereby providing consumers with a larger set of choices. By limiting power and relying on spectrum with low propagation, unlicensed bands avoid interference, rendering the need for property rights irrelevant. In fact, some of the most important innovations in wireless communications are intimately linked to Wi-Fi for gaining access. This is particularly relevant in the 6 GHz band for the development of Very Low Power devices.

- **Supporting innovative business models:** By providing consumers with additional service choices, unlicensed spectrum also supports the development of innovative business models. The causality between unlicensed spectrum and innovation occurs at multiple levels. First, firms developing new applications in an unlicensed spectrum environment do not need approval from the operators of cellular networks. On the other hand, a firm that attempts to develop a product running on spectrum licensed to a set of exclusive holders faces a "coordination failure" barrier (Milgrom et al., 2011). Along those lines, if the product requires the acceptance and coordination of multiple license holders (say multiple cellular network operators), the innovator must negotiate with every one of them (unless it is willing to face the problem of restricting its market reach).

- **Expanding access to communications services**: In addition to the applications discussed above, technologies operating in unlicensed spectrum can bridge the broadband coverage digital divide. Further developments in the areas of spectrum sensing, dynamic spectrum access, and geolocation techniques (Stevenson et al., 2009) have improved the quality of wireless service based on unlicensed spectrum technologies, substantially extending the geographic range of conventional 802.11 standard and providing cost-efficient access in rural settings. This last dimension will be particularly critical to Brazil.

2.2. The decision of assigning spectrum to unlicensed use in Brazil

As mentioned above, ANATEL approved on May 6, 2020 the unlicensed use of spectrum in the 6 GHz band (5,925–7,125 MHz). In reaching a decision of allocating the 6 GHz band for unlicensed use, ANATEL is evaluating two options: (i) affect the entire 6 GHz band (that is to say allocate 1,200 MHz) for unlicensed use (which we label the United States-Korean model), or (ii) allocating only 500 MHz (the European model).

The United States model

In October, 2018, the FCC presented a Notice of Proposed Rulemaking (NPRM) that recommended opening the 6 GHz band to unlicensed operations. In particular, the Commission sought comment[9] to its proposal to open the band's full 1,200 MHz (5.925-7.125 GHz) to unlicensed devices. The FCC considered two classes of devices:

- Standard power access points: In the 5.925-6.425 GHz and 6.525-6.875 GHz sub-bands, unlicensed access points would be permitted to transmit both indoors and outdoors under the control of an automated frequency coordination system at power levels that are currently permitted in the 5 GHz band.

- Low Power Indoor (LPI) devices (restricted to indoor) (LPI), operating approximately four times lower than standard Wi-Fi, and required to be non-weather proofed, plugged into the wall, and authorized to use only 1/4 of the power of standard-power Wi-Fi (i.e., 250 milliwatts conducted power), which excludes them from the need to be frequency coordinated. This is the closest designation to current Wi-Fi.

In April 2020, the US Federal Communications Commission unanimously voted to allow the two classes of unlicensed devices to operate in the 6 GHz band. Low power indoor devices were permitted to operate throughout the 1,200 MHz. Standard power access points were allowed to operate in 850 MHz in the sub bands described above. As a result, the capacity available for Wi-Fi is quadrupled. The higher capacity available with 6 GHz suggests that the actual speed of the signals will be higher than the current ones at 2.4 and 5 GHz. One or two Gbps could be reached with a smartphone capable of Wi-Fi 6E when using the 160 MHz channel. Under this configuration, routers have access to seven new 160 MHz channels.

Concurrent with its decision to permit standard power and low power indoor devices, the Federal Communication Commission proposed a third category of 6 GHz RRRC Equipment -- Very Low Power devices (VLP), authorized to power levels 160 times lower than standard-power Wi-Fi, and permitted to be used indoors or outdoors in certain sub-bands, and not requiring frequency coordination because they would operate with 60 times less power than standard-power Wi-Fi. These VLP devices would be capable of operating using multiple extremely wide channels (160 MHz) with sub-millisecond latency performance. The category includes AR/VR headsets, Ultra High Definition Video Streaming, high-speed[10] tethering (watches, ear pods) or entertainment devices in the automobile.

The Korean model

[9] *6 GHz NPRM.*
[10] FCC ex parte notification from Apple Inc., Broadcom Inc., Facebook Inc., Google LLC, Hewlett Packard Enterprise, Intel Corp., Marvell Semiconductor Inc., Microsoft Corporation, Qualcomm Incorporated (July 2, 2019).

In June 2020, South Korea's Ministry of Science and ICT (MSICT) issued a proposed "amendment of technical standards" for public consultation[11]. A decision is expected to take place later this year for releasing the entire 6 GHz band – meaning 5925-7125 MHz –for indoor operation in September of 2020, while outdoor use will follow in 2022[12]. For Korea, this will be the first Wi-Fi frequency upgrade in sixteen years.[13]

The European model

Similar consultations are underway in Central European Countries with regard to the allocation of the 6 GHz band, while OFCOM has already reached a decision for Great Britain. However, rather than releasing the entire band, the European approach considers only the lower 500 MHz part of the band. OFCOM allocated the lower 6 GHz band (5925-6425 MHz) for unlicensed use supporting Wi-Fi connectivity indoors and limited outdoor coverage and traffic hand-off[14]. The lower band is adjacent to the currently used 5 GHz band, has similar mid-range propagation characteristics and offers, wide, non-overlapping channels. OFCOM estimates that this band in combination with currently used 2.4 GHz and 5 GHz frequencies, can handle between 200 and 400 client devices per access point and a maximum theoretical data rate of 6.6 Gbps. On July 24, 2020 OFCOM made the final decision to make 500 MHz available for unlicensed use low power indoor and very low power outdoor use as an initial matter[15]. The purpose in limiting the allocation to 500 MHz is to initially show Wi-Fi can benefit from the lower part of the band and then investigate the upper part[16]. In the words of OFCOM, "we will continue to review use of the upper 6 GHz band to determine what the optimal use may be".[17]

In addition, in response to a request from the European Commission to investigate spectrum between 5,925 to 6,425 MHz, the CEPT (*Conférence Européenne des Administrations des Postes et des Télécommunications*) has issued a technical report to the European Commission on the feasibility of Wi-Fi in the 6 GHz band[18]. The purpose is to develop a harmonized approach for the 48 CEPT countries, which includes in addition to the 28 EU countries, Switzerland, Turkey and Russia, among others. In this case, routers will have access to three 160 Mbps channels. The underlying rationale for investigating only the 5,925 to 6,425 band (500 MHz) is that European countries have critical services in upper part of the 6 GHz band (e.g. large amount of point to point fixed services, earth to space communications, road intelligent traffic systems and communication-based train control, and some radio astronomy sites).

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[11] Hetting, C. (2020). "South Korea could become Asia's first 6 GHz nation". *Wi-Fi News* (June, 27).
[12] Yonhap (2020). "Unlicensed frequency band to boost Wi-Fi speed, smart factory penetration: ministry", *The Korea Herald*, (June, 27).
[13] Hetting, C. (2020). "South Korea could become Asia's first 6 GHz Wi-Fi nation". *Wi-Fi Now* (June, 27).
[14] Blackman, J. (2020). "UK to release 6 GHz and 100 GHz spectrum for Wi-Fi in smart homes, offices, factories". *Enterprise IoT insights* (January, 27).
[15] OFCOM (2020). *Statement: improving spectrum access for wi-fi – spectrum use in the 5 and 6 GHz bands* (July 24).
[16] Ebbecke, Ph. (2019). *Road to 6 GHz in Europe*. Presentation to WLPC Prague 2019
[17] OFCOM (2020). *Improving spectrum access for Wi-Fi*. London, p.21.
[18] Hetting, C. (2019). "Europe's process to release 6 GHz spectrum to Wi-Fi on track, expert says", *Wi-Fi Now* (June, 2).

3. METHODOLOGIES FOR ASSESSING THE VALUE OF ALLOWING UNLICENSED USE OF THE 6 GHz BAND IN BRAZIL

The objective of the study is to provide an assessment of the economic value to be derived by allowing unlicensed use in the 6 GHz band in Brazil. Our approach to measuring economic value of unlicensed spectrum focuses first on the new economic growth enabled by the additional unlicensed spectrum channels in the 6 GHz band. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior literature measuring the economic gains of new goods. In measuring the GDP direct contribution, we strictly consider the revenues added "above and beyond" what would have occurred had the unassigned spectrum been licensed.

Beyond GDP contribution, we add to this analysis by measuring the economic surplus triggered by the adoption of the technologies operating in the unlicensed network bands. The underlying assumption of this approach is that the unlicensed spectrum resource generates a shift both in the demand and supply curves resulting from changes in the production function of services as well as the corresponding willingness to pay. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is whether Wi-Fi, enabled by unlicensed spectrum, represents a positive contribution to wireless carriers' CAPEX and OPEX insofar as they can control their spending while meeting demand for increased wireless traffic. From an economic theory standpoint, the wireless industry can then increase its output, yielding a marginal benefit exceeding the marginal cost. This results in a shift in the supply curve by a modification in the production costs. To quantify incremental surplus derived from the adoption of technologies operating in the 6 GHz band, we itemize the number of technologies and applications intricately linked to this environment. We complement the concept of producer surplus with an assessment of the consumer surplus. The assessments of economic value have been estimated for the years 2020 to 2030.

At the aggregate level, the methodology relied upon in this study is similar to the one used in prior studies by the author[19], whereby the different sources of economic value were estimated independently and then aggregated within a single value (this allows cumulating GDP impact, with consumer and producer surplus[20]). Along those lines, we proceeded to

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[19] Katz, R. (2014a). Assessment of the economic value of unlicensed spectrum in the United States. New York: Telecom Advisory Services. Katz, R. (2014b). Assessment of the future economic value of unlicensed spectrum in the United States. New York: Telecom Advisory Services. Katz, R. (2018). A 2017 assessment of the current and future economic value of unlicensed spectrum. Washington, DC: Wi-Fi Forward. Katz, R. (2018). The global economic value of Wi-Fi 2018-2023 . New York: Telecom Advisory Services. Katz, R. (2020). Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands. Washington, DC: Wi-Fi Forward.

[20] We consider that cumulating GDP effect and producer surplus on equipment sales is reasonable given that the impact on GDP is fundamentally attributed in our models based on historical data to speed increase and not to producer surplus driven by equipment sales triggered by new unlicensed spectrum allocation. On the other hand, CAPEX savings incurred by wireless carriers incurred by offloading traffic to Wi-Fi has been occurring for a while and could be included in the GDP model estimates. Therefore, in this particular case, the effect derived from CAPEX savings will be excluded from totals to avoid double counting.

identify the sources of economic value, estimated their impact, and then combined them in the aggregate. The area of impact of each source of value varies (see table 3-1).

Table 3-1. Sources of Value of 6 GHz Band in Brazil

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhance coverage and improve affordability	Improve affordability associated with broadband provision and increasing access sharing in the WISP sector		Faster speed of access for WISP subscribers
Increased speed by reducing Wi-Fi congestion	Benefits of eliminating router bottleneck in high speed connections by increasing speed of in-door Wi-Fi		Consumer surplus from increasing speed
Wide deployment of Internet of Things	Spillovers of IoT deployment on productivity on key sectors of the Brazilian economy (e.g. automotive, food processing, logistics, etc.)	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment	
Reduction of enterprise wireless costs		Cost reduction of enterprise use of wireless communications	
Deployment of AR/VR solutions	Spillovers of AR/VR deployment on the Brazilian economy	Margins of ecosystem firms involved in AR/VR deployment	
Enhanced deployment of municipal Wi-Fi	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband
Deployment of Free Wi-Fi Hot Spots	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband
Aligning spectrum decision with other advanced economies	Potential opportunity of creating a Wi-Fi equipment manufacturing sector	Benefits of economies of scale of aligning Brazil with US (lower equipment prices)	
Enhancing the capability for cellular off-loading		CAPEX reduction derived from offloading wideband wireless traffic to carrier grade Wi-Fi hot spots	

Source: Telecom Advisory Services analysis

3.1. Enhance broadband coverage and improve affordability

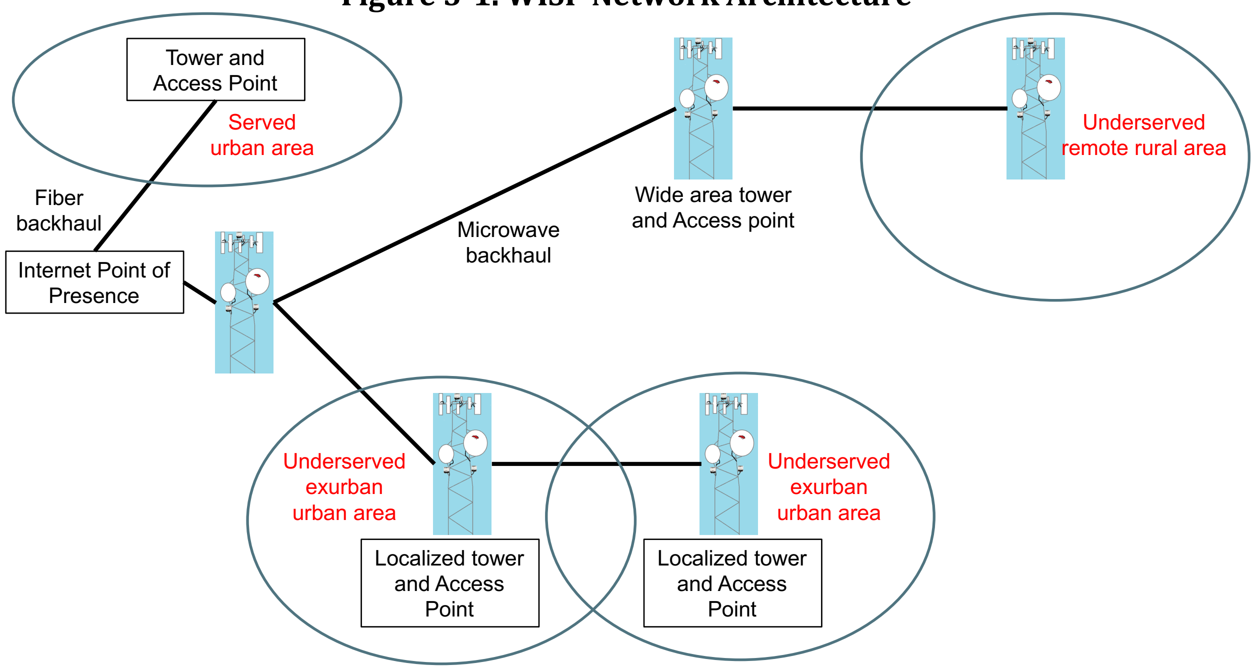
This analysis will focus on estimating the impact of the 6 GHz decision on the wireless ISP (WISP) industry in Brazil. While accounting for 1.9 million lines, the WISPs represent a critical contributor to tackling the country's persistent digital divide. Internet adoption in Brazil is estimated to have reached 75%[21], while mobile broadband unique subscriber

[21] Extrapolation to 2020 from ITU data.

penetration is estimated at 61.60%[22], and fixed broadband adoption is 46.35% of households[23]. Broadband non-adopters are, as expected, concentrated on the lower income population in urban areas and rural geographies. As shown in chapter 4, WISPs tend to have a primary focus on the vulnerable population and part of their deployment is in rural municipalities. In that sense, it is critical to understand how these players could benefit from the 6 GHz allocation. As background, the WISP association in the United States was a key stakeholder supporting the FCC decision to allocate the 6 GHz spectrum[24]. This has been acknowledged by ANATEL[25], although the specificities of the Brazilian context render the benefits to be derived by the 6 GHz band to the country's WISPs more important.

For reference, the network architecture of a WISP is composed of backhaul (either fiber optic or microwave based) to link the internet point of presence to local access points. Each access point relies on Wi-Fi technology to provide broadband service to consumers (see figure 3-1).

Figure 3-1. WISP Network Architecture



Source: Telecom Advisory Services

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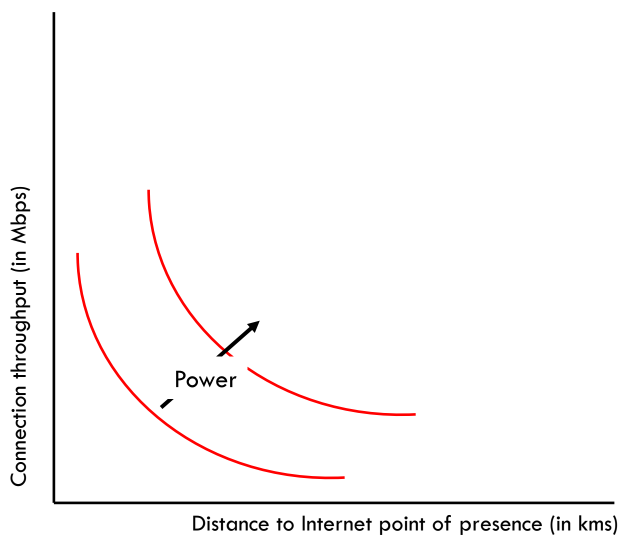
[22] GSMA Intelligence (2020).
[23] CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019
[24] WISPA (2020). *Letter to the FCC Commissioners* (March 5).
[25] See ANATEL. ANALISE 29/2020/CB. Art. 4.45: "a disposnibilização da faixa de 6 GHz para uso não licenciado por aplicações de Wi-Fi 6 parte da expecta vã do órgão regulador norte-americano de que o Wi-Fi: (i) permita a realização de politicas publicas de expansão de cobertura de banda larga, especialmente em áreas rurais; e, (ii) seja indutor do surgimento de tecnologias e serviços inovadores, que demandarão alternativas de conectividade de baixo custo, com redução dos níveis de latência e incremento das velocidades de conexão."

Access to the 6 GHz spectrum band could have an impact on the WISP business at four levels:

- **Enhanced point to point microwave-based backhaul capacity which allows WISPs to increase coverage**: the link between access points is generally handled by microwave links, which under current spectrum use, the bands are very crowded, with higher interference. Currently, most Brazilian WISPs rely on unlicensed spectrum in the 2.4 GHz and 5.8 GHz bands for backhauling purpose. In Brazil spectrum between 5925-7075 MHz is currently allocated only for fixed service (links) and fixed satellite service, which means that under 6GHz allocation, Brazilian WISPs should be able to operate across the entire band, thereby yielding higher power point-to-point links. By moving backhaul links to 6 GHz with no limitation on radiated power, WISPs could extend further the backhaul into more remote areas. A critical benefit of this move will be that WISP could further penetrate rural areas, thereby addressing part of the digital divide. As of 2020, 4G coverage reaches 95% of the Brazilian population, which leaves 10,568,000 Brazilians unserved by cellular broadband. As expected the distance that WISPs could enhance their backhaul coverage is a function of path loss and has an impact on available speed to be delivered to the consumer. Along those lines, the higher the power to be available, the lower the path loss (see conceptual graphic 3-1).

Graphic 3-1. Point to point backhaul distance



Note: This relationships assumes free space path loss with no obstructions.
Source: Telecom Advisory Services

Beyond extending their point to point backhaul links, by having the large spectrum in 6 GHz available, different WISPs could operate in similar areas with little risk of interference or serve specific communities.

- **Increase in speed to existing subscribers**: The consumer welfare of WISP customers is expected to benefit from the 6 GHz allocation and the consequent increase in access point performance, which will yield faster service. This will materialize in terms of an increase in speed. Beyond the benefit to the existing subscriber base, the increase in throughput provides a more efficient use of infrastructure for sharing lines across subscribers, a feature very popular among WISP subscribers in Brazil (see below).

- **Increase coverage per access point:** under use of 2.4 GHz and 5.8 GHz spectrum, WISP served areas range between 3.5 kms in urban settings to 12 kms in rural areas. Coverage is a function of spectrum frequency and power (the higher the frequency the higher the path loss, which is compensated by an increase in power). In order to increase coverage under standard power allowance, increased coverage could be gained by bonding channels (a technology not yet frequently used by WISPs), available by the 6 GHz allocation .

- **Higher capacity per access point**: As stated in interviews, Brazilian ISPs tend to currently have the capacity of handling 50 subscribers per 20 Mbps channel. The use of the lower part of the 6 GHz channel would allow the WISPs to increase the number of subscribers to be handled by access point, particularly in the closer areas. OFCOM estimates that the cumulation of 2.4 GHz, 5.8 GHz and 6 GHz could increase the number of subscribers per access point to at least 200.

Contribution to consumer surplus as a result of increasing broadband speed

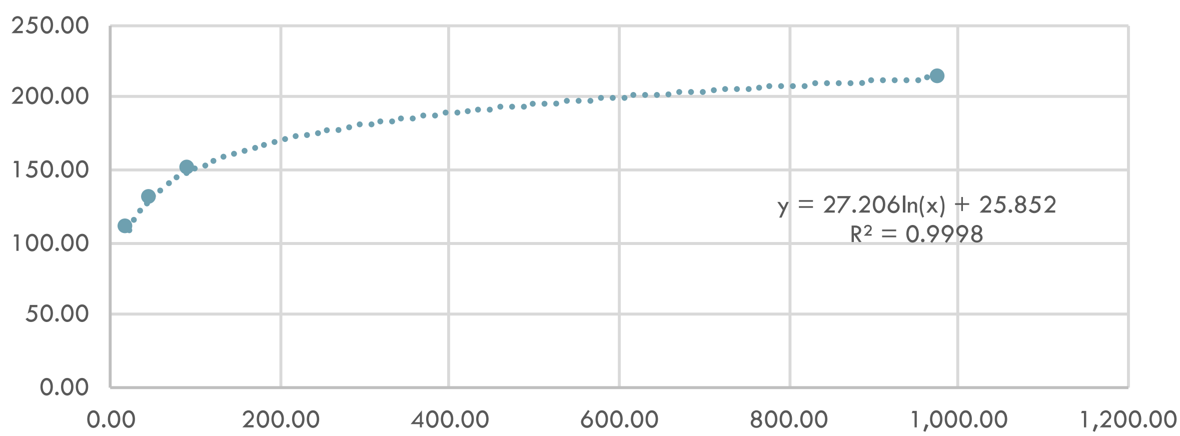
Consumer surplus is defined as the value that consumers receive from purchasing a product for a price that is less than what they would be willing to pay. Early on, Rosston et al. (2010) noted that, in addition to the benefits that consumers receive from broadband adoption (quick access to large amounts of information for learning and health services, access to the world's largest portal for social and entertainment services and the potential for savings from online shopping), one must also consider consumer preferences and benefits received from the nature of the service, which include speed of access and reliability.

Most studies of consumer surplus derived from faster broadband speed are based on primary research, where users stipulate the amount they would be willing to pay for broadband service (Savage et al. (2004); Greenstein and McDewitt (2011); Liu et al. (2017). All studies on consumer surplus focus the assessment of how US consumers react to variations in price according to their data usage. For example, Nevo et al. (2015) studied hour-by-hour Internet usage for 55,000 US subscribers facing different price schedules. They concluded that consumer surplus for speed is heterogeneous. Consumers will pay between \$0 to \$5 per month for a 1 Mbps increase in connection speed, with an average of \$2.[26] In addition, they stipulated that, with the availability of more content and applications, consumers will likely increase their usage, implying greater time savings and a greater

[26] Heterogeneity in willingness to pay for broadband was also highlighted by Rosston et al. (2010).

willingness to pay for speed. At the time of the study, the increase in willingness to pay at high speeds dropped by approximately $0.11 per Mbps. This is confirmed by a more recent study. Liu et al. (2017) administered two national, discrete choice surveys of US consumers to measure households' willingness-to-pay for changes in price, data caps, and speed. The authors found that the valuation of bandwidth is highly concave, with lesser added value beyond 100 Mbps (see Graphic 3-1).

Graphic 3-1. Log Curve of relationship between broadband speed and consumer surplus (based on Nevo et al., 2016)



Source: Liu et al.(2018); Telecom Advisory Services analysis

As reported in this study, households are willing to pay about US$2.34 per Mbps (US$14 total) monthly to increase bandwidth from 4 Mbps to 10 Mbps, US$1.57 per Mbps (US$24) to increase from 10 to 25 Mbps, and US$0.02 per Mbps (US $19) for an increase from 100 Mbps to 1000 Mbps. In order to adapt the curve in Graphic 3-1 to Brazil, we compared a 35 Mbps (Claro) and 50 Mbps plan (Vivo) for R$ 119.99 (US$24.12) with the average price of a 60 Mbps plan in the US (US$29.99). The ratio between both price points was 80.43 %. This value was used to modify the results of the curve above. From a perspective of service quality, it is estimated that the allocation of 6 GHz would allow the delivery of in-door capacity of 1 GB speed download speed and 6 Ms. latency.

Increase coverage per access point would allow to stabilize real prices and increase affordability

The allocation of the 6 GHz band to unlicensed use would allow the Brazilian WISPs to potentially increase their subscriber base within their same coverage footprint[27]. As mentioned above, the allocation of the 6 GHz band to unlicensed use would allow WISPs to sign up new devices and increase download speed, which would trigger several simultaneous positive effects. As an example, the temporary assignment of spectrum by the

[27] Based on the assumption that the technical rules for standard power access points operated by WISPs in the 6 GHz are similar to the technical rules (e.g. radiated power limit, radiated power spectral density, etc.) established for access point operated by WISPs in the 2.4 GHz and 5 GHz bands.

FCC to deal with the COVID-19 pandemic allowed WISPs in the United States to immediately increase their subscriber base between 20% and 30%.

Recognizing the economies of scale in telecommunications services, an increase of the user base would allow service providers to lower their operating costs. Under a conservative scenario assumed within our study, prices will remain stable in a context of increasing GDP per capita. As a consequence, affordability would increase for those potential subscribers that indicate that they do not purchase broadband service because of its cost. A survey conducted by Cetic.br in 2019 indicates that 7.46% of households in Brazil (or 5,295,904 households) do not purchase broadband because of its cost (this percent increases to 13.32% in rural areas)[28]. With an increase in affordability, the penetration of broadband will grow.

Higher capacity per access point

As mentioned above, a second-order effect on broadband adoption from WISP providers relates to an increase in household sharing ratio as result of increased access point performance. As a result of lower income population concentration, WISP Wi-Fi lines are frequently shared across neighbors. According to a CeTic.Br survey[29], in 2019 12.83 % of households in Brazil access broadband by sharing a fixed broadband connection with a neighbor.

The increase in affordability combined with an enhancement of the capability to share lines will result in the growth of broadband connections. According to econometric models developed by the authors for the International Telecommunication Union, an increase of 10 percent in fixed broadband in Latin America and the Caribbean yields and growth of 1.5745 percent in the GDP[30].

The sum of all these convergent effects on WISP performance is displayed in figure 3-1.

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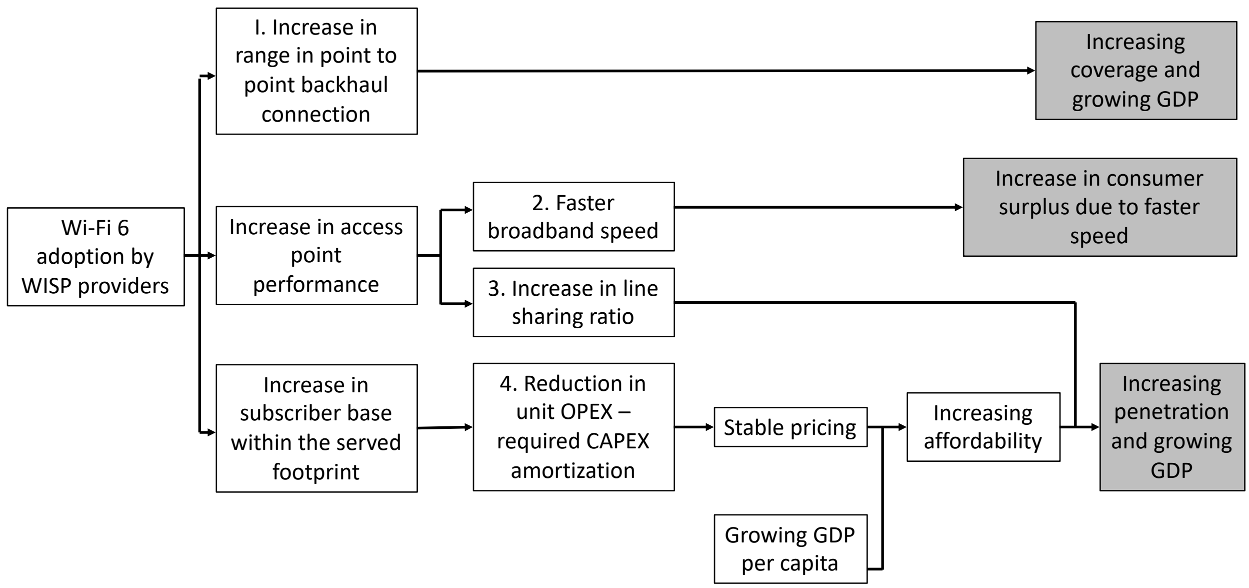
[28] CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), *Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios* 2019.

[29] CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019/2018/2017/2016/2015

[30] Katz, R. and Callorda, F. (2018). *The economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the Americas*. Geneva: International Telecommunications Union, p. 10

Figure 3-1. Economic Impact of 6 GHz on WISP performance



Source: Telecom Advisory Services

In a theoretical level, the sum of economic impact of the 6 GHz allocation on the WISP performance could be specified as follows:

$$\text{Economic effect of 6 GHz in WISPs} = a_1 + a_2 + a_3 + a_4$$

Where,

a_1 Extended coverage due to longer P2P backhaul (impact on GDP)
a_2 Added consumer surplus due to faster speed (impact on consumer surplus)
a_3 Better coverage per access point (impact on GDP)
a_4 Higher sharing ratio per access point (impact on GDP)

3.2. Increase speed by reducing Wi-Fi congestion

The economic value of allocating the 6 GHz band to unlicensed use reduces router congestion, increases Wi-Fi throughput, and has a net effect of accelerating broadband speed. This result does not affect all fixed broadband connections, although its impact among high speed broadband users has a net effect increasing average broadband speed at the customer premise and device level. The increase in average speed has two types of economic contributions: a growth in GDP (also called the "return to speed"), and an increase in consumer surplus. This transitive causal chain can be disaggregated into three effects:

- A removal of Wi-Fi congestion has an impact on broadband speed at the device level in the customer premise;
- An increase in broadband speed for high speed users in turn drives a contribution to the Brazilian GDP;

- An increase in broadband speed increases the willingness to pay of users of high speed broadband access.

When a consumer accesses the Internet, the speed of access at the device level is a function of the performance of the fixed and/or wireless network and the router's throughput. The net result differs from the speed of the broadband connection. For example, if a user purchases a 20 Mbps fixed broadband line, it is highly unlikely that the Wi-Fi router will become a performance bottleneck. A dual band router can deliver peak speeds of 1.2 Gbps on 2.4 GHz, 4.8 Gbps on one 5 GHz radio, and 4.8 Gbps on the other 5 GHz radio. Based on the current 2.4 GHz and 5 GHz allocation, dual router performance is estimated to be 266.50 Mbps (which results from assuming an even split of traffic between the 2.4 GHz band (at 173 Mbps) and the 5GHz band (at 360 Mbps)). This does not mean, however, that each user is receiving the total speed. Through the use of multiple bands and spatial streams, routers commonly today have total throughput capabilities well in excess of the speeds they can enable for individual devices. For example, a high-end 802.11ax device can, in theory, handle total throughput of 4.8 Gbps, but each user will receive a throughput under 200 Mbps.[31] Under this circumstance, if the user acquires a 150 Mbps fixed broadband line, the router becomes a "choke" point in the network, and the speed experienced by a consumer will not be equivalent to that delivered by the fixed network. This argument becomes even more relevant under a scenario of future deployment of 5G networks capable of delivering up to 150 Mbps.

Research on the economic contribution of broadband speeds uniformly concludes that faster Internet access has a positive impact on GDP growth. Three types of effects explain this relationship. First, faster broadband contributes to an improvement of labor productivity resulting from the adoption of more efficient business processes. Marketing of excess inventories and optimization of the supply chain are two of the effects that might be generated. Second, faster connectivity yields an acceleration of the rate of introduction of new products, services, and the launch of innovative business models. Third, the acceleration of broadband speeds drives a set of network externalities resulting in a restructuring of industry value chains (in other words, faster communications allow enterprises to either outsource operations without any disruption risk or relocate functions to areas with more advantageous input costs). The compilation of the research evidence generated so far in four econometric studies[32] confirms the existence of these effects (see Graphic 3-2).

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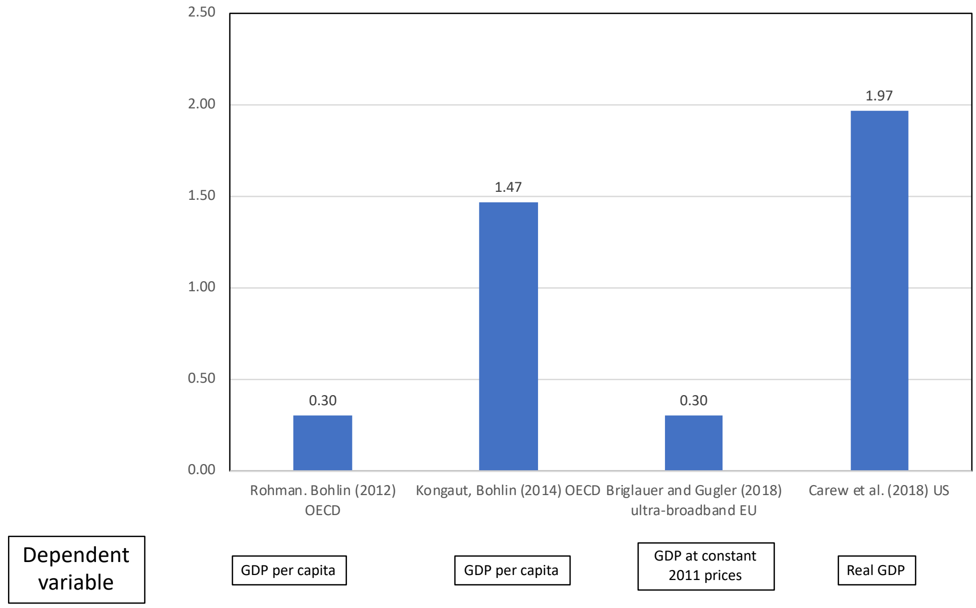
[31] Estimate provided by Broadcom. This refers to the throughput received by each user device (PC, tablet, etc.) within the user premise.

[32] We have selected only four studies to review, although research has yielded many more papers (see, for example, Ford, G. (2018). *Is Faster Better? Quantifying the Relationship between Broadband Speed and Economic Growth* . Phoenix Center Policy Bulletin No. 44. Grimes, A., Ren, C., and Stevens, P. (2009). *The need for speed: Impacts of Internet Connectivity on Firm Productivity.* MOTU Working Paper 09-15. Mack-Smith, D. (2006). *Next Generation Broadband in Scotland* . Edinburgh: SQW Limited).

Graphic 3-2. Studies measuring the GDP impact on Broadband Speed (impact of 100% increase in speed on GDP) (%)



Source: Compiled by Telecom Advisory Services

As indicated in Graphic 3-2, while all four studies coincide in concluding that broadband speed has an impact on GDP, the range of contribution varies: 100% (or doubling) increase of broadband speed generates a contribution to GDP ranging from 0.30% to 1.97%. Some of the difference is explained by the methodologies and variables used. For example, Carew et. al (2018) did not include broadband adoption as an independent variable, which means that the effect of speed on GDP subsumes broadband penetration. In other cases, the difference can be explained by the timing of data used. For example, Kongaut, Bohlin (2014) rely on a data panel between 2008 and 2012, while the time series of Rohman, Bohlin (2012) ends in 2010, both moments when the average broadband speed was 8.3 Mbps, which in turn resulted in high impact. That being said, the evidence of the positive effect with regards to the contribution of broadband speed to GDP growth remains consistent.

3.3. Wide deployment of Internet of Things

The economic relevance of IoT has already been well established by numerous analysts. IDC estimated that the 2020 IoT world market for overall IoT solutions was approximately US$1.7 trillion, and US$3.29 billion in Brazil alone for 2021. The economic importance of IoT for Brazil has been clearly established in its national IoT plan[33]. Simultaneously, industry participants have been clear in stipulating that this importance can only be fulfilled if a number of barriers ranging from business process redesign to technology standards are addressed[34]. Spectrum availability is one of the barriers on IoT development. While IoT roll-out in Brazil has already been proceeding for a number of years, large scale deployment has suffered from the risk of congestion. The assignment of 1200 MHz in the 6 GHz band will

[33] BNDES (2017). *Estudo Internet das Coisas: um plano de ação para o Brasil*.
[34] CompTIA (2016). *Sizing up the Internet of Things*.

result in a broader scale IoT deployment. Along those lines, the additional unlicensed spectrum recommended by ANATEL will mitigate congestion and, therefore, provide a boost to the growth of IoT.

The economic value linked to a wider deployment of IoT is based on two sources: (i) the development of firms within the IoT ecosystem, which generate a producer surplus (i.e. margin) by selling their output in Brazil, and (ii) the spillover of IoT on the economy, which is focused on those sectors that are IoT intensive (e.g. logistics, Health Care, Natural Resources).

With respect to the first source of value, it is important to distinguish the different components of the ecosystem, which include hardware, software, and services. As is clear, this distinction is grounded in traditional IT components, although their combination within the IoT value proposition represents a different format. The ecosystem contributing to delivery of the IoT economic value comprises multiple types of companies (see table 3-2).

Table 3-2. IoT Ecosystem

Categories	Components	Type of firms
Hardware	Sensors/chips	Manufacturers of sensors and compute components
	Miniature devices	Specialized providers of small scale sensors
	Connectivity	Manufacturers of network equipment
Software	Apps	Connectivity software
	Cloud service providers	Software provided by public cloud providers
	Platform providers	New operating systems
	Carriers	Telecom players providing cloud-based solutions
Services	Systems integration	Integration of devices and components within a single platform
	Analytics	Providers of data warehousing and analytic tools
	IT services	Platform providers
	Security	Developers of security protocols and technologies

Source: Telecom Advisory Services

Within the second source of value, the use cases associated with IoT (such as predictive maintenance, asset tracking, smart grid demand management, traffic coordination, and the like) have an impact on GDP growth.

3.4. Reduction of enterprise wireless costs

The increase in unlicensed channel capacity enables more extensive delivery of ubiquitous, high throughput wireless connectivity across multiple access points in business facilities, such as industrial plants, enterprise campus, and the like. This will allow firms to leverage Wi-Fi infrastructure and generate further savings in the use of wideband wireless communications.

When the 6 GHz band is opened up and added to the existing unlicensed bands in 2.4 GHz and 5.8 GHz, the combined spectrum will be able to support eight 160 MHz channels or three 320 MHz channels, which will be a source of economic value for production units. The first effect will result in the enabling of faster in-door broadband speeds. Moreover, the addition of channels in 6 GHz will enable providers to deliver fast next-generation speeds to businesses, industrial facilities, hospitals, ports, railyards, and airports across the country. The estimation of economic value in this domain will focus around the new applications and use cases. In addition, the additional spectrum will allow the support of a high number of devices on a single access point. Some Wi-Fi 6 solutions can handle up to 1,500 devices, which makes them ideal for enterprise applications.

3.5. Deployment of AR/VR solutions

Virtual Reality (VR) is already being used within a wide array of areas, ranging from the gaming industry and entertainment, to training and simulation, in particular in the medical field. Other areas of application include education and culture, sports, live broadcasting, real estate, advertising, architecture and the arts. On the other hand, Augmented Reality (AR) has an almost limitless range of uses in a wide variety of areas, be it commerce, technical applications, work processes or education. VR and AR serve both consumers and professional users who can be private and public. The AR/VR solutions market is developing at a fast pace driven by a broad range of applications. This development yields two effects similar to the one reviewed in IoT.

The development and diffusion of AR/VR applications in the production side of the economy is being driven by an ecosystem comprised of firms ranging from software development to hardware production and applications development. The margins of firms involved in this endeavor represent producer surplus.

On the other hand, the adoption of AR/VR among Brazilian enterprises will in turn have spillover effects on productivity, thereby contributing to the growth of GDP. The spillover effects range from improved training to the acceleration of product design and delivery. For example, automotive companies are already incorporating VR in their product development processes to reduce the time incurred between initial design and physical modelling. AR glasses also help warehouse workers provide parts information for engineers and technicians in the field. Finally, AR/VR solutions can be used to sell and showcase products in retailing.

3.6. Enhanced deployment of municipal Wi-Fi

Municipal Wi-Fi provides free Internet access to the population at large. In many cases, municipalities aiming to develop a smart city infrastructure require the deployment of Wi-Fi networks in public places to facilitate Internet access for their citizens. Brazilian municipalities have been very aggressive in developing Wi-Fi networks. Brazil has 5,570 municipalities, subdivided in 10,123 districts[35]. It is estimated that 2,134 Brazilian municipalities already offer free Wi-Fi service[36]. Consumers who do not have broadband at home because they lack economic resources to acquire service can rely on municipal Wi-Fi to gain Internet access.

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[35] Of these, 9,807 districts have a population of under 100,000, and 1,284 are considered to be urban.

[36] TAS Analysis using IBGE, *Pesquisa de Informações Básicas Municipais* - 2014 data

However, Wi-Fi infrastructure relying only on 2.4 GHz and 5.8 GHz bands is exposed to service degradation as well as inability to support a large user base. Municipal Wi-Fi is an application that is in critical need of additional spectrum to satisfy the growth in the number of clients but also to deal with interference from other devices operating in competing frequencies. As an example, the 2.4 GHz band currently handles may appliances and devices on wireless standards such as Bluetooth and Zigbee, creating significant interference for Wi-Fi.

We will assess the economic benefit of the 6 GHz allocation focusing on its capacity to increase speed of access with the consequent generation of consumer surplus while at the same time providing the economically disadvantaged population with access to the Internet.

3.7. Deployment of Free Wi-Fi Hot Spots

In addition to Municipal Wi-Fi, Free Wi-Fi sites represent a cost-advantaged approach for consumers "on the go" to access the Internet. As of 2020, there are approximately 6.2 million[37] public Wi-Fi hot spots in Brazil of which 2,325,921 are free, distributed as follows (see Table 3-3).

Table 3-3. Brazil: Number of Free Wi-Fi Spots (2020)

City	Number
Sao Paulo	534,000
Rio de Janeiro	263,000
Salvador	47,000
Fortaleza	42,000
Belo Horizonte	86,000
Brasilia	66,000
Campinas	36,000
Recife	47,000
Porto Alegre	55,000
Manaus	27,000
Curitiba	63,000
Belem	13,000
Goiania	30,000
Maceio	12,000
Other	1,005,000
Total	2,326,000

Source: Wiman (2020).

Cisco projects that by 2023, there will be 23.8 million public hot-spots in Brazil.

The assessment of economic value of allocating 6 GHz spectrum to free Wi-Fi hot spots will be conducted in a similar way as in the case of Municipal Wi-Fi: in other words, free hot spots supported by technology associated to 6 GHz will be capable of increasing the access speed

[37] Interpolated from 4.6 million in 2018 and 23.8 million in 2023 as estimated by Cisco Visual Networking Index.

(with consumer surplus implications) and providing an access point to the population who does not have broadband service.

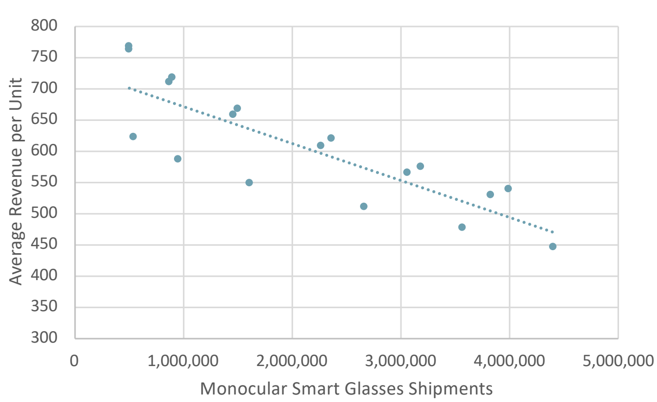
3.8. Aligning spectrum decision with other advanced economies

By allocating spectrum in the 6 GHz, Brazil will not only alleviate the pressure on unlicensed spectrum resulting from explosive Wi-Fi usage, but will also make a decision with implications for cost of inputs for Brazilian firms and for the country's industrial policy.

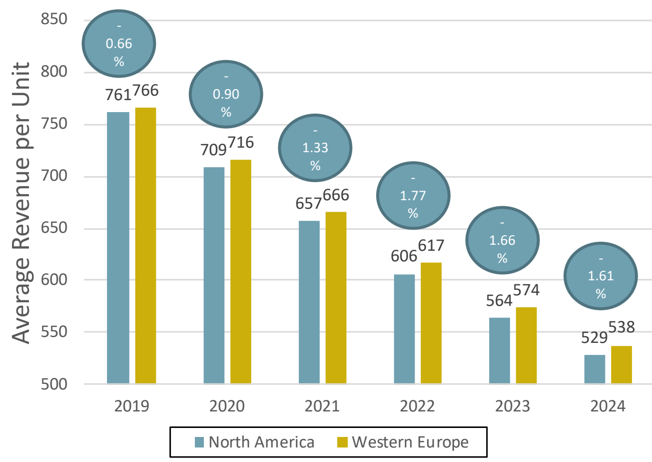
A comparative assessment of unit average selling price of AR/VR equipment indicates that the United States has an economic advantage (lower cost) over Europe, resulting from economies of scale (see graphic 3-2).

Graphic 3-2. Example of AR/VR Equipment: Economics of production(*)

Regional Markets of Monocular Glass Shipments



Monocular Glass Unit Price: US versus Europe



(*) This chart provides an example of one segment of the AR/VR equipment market – Monocular Smart Glasses – and does intend to present the total market.
Notes: 1) Chart on left comprises Data for North America; Western Europe and Asia-Pacific
2) The Unit price of the chart on the right was calculated by Telecom Advisory Services dividing ABI Research data for total revenues by total shipments
Source: ABI Research; Telecom Advisory Services analysis

As indicated in the left hand chart, the production of AR/VR equipment is, as expected, driven by economies of scale. As a result, the chart of the right indicates a price advantage residing within the United States. Consequently, it might make sense to align Brazil's 6 GHz spectrum allocations issue with the US model in order to allow Brazilian firms to benefit from lower input prices.

Secondly, the Brazilian market for equipment and services in areas related to implementation of the 6 GHz amounts to US$3.13 billion in 2020 but will reach US$9.23 billion in 2025 (see table 3-4).

Table 3-4 Brazil: Sales in markets impacted by the 6 GHz decision (in US$ billion) (2020-25)

Market	Categories	2020	2025
Augmented Reality/Virtual Reality	Hardware	$ 0.05	$ 0.55
	Software and applications	$ 0.15	$ 2.34
	Subtotal	$ 0.20	$ 2.89
IoT	Hardware	$ 0.40	$ 1.17
	Software and services	$ 2.11	$ 4.99
	Subtotal	$ 2.75	$ 6.17
Wi-Fi devices	Home networking devices	$ 0.02	$ 0.02
	Wi-Fi enabled devices	$ 0.08	$ 0.07
	Enterprise access points and controllers	$ 0.08	$ 0.08
	Subtotal	$ 0.18	$ 0.17
Total		$ 3.13	$ 9.23

Note: ABI Research provides an estimate of the AR/VR market through 2024 for Latam.
The AR/VR market for Brazil was calculated by prorating the Latam market from ABI Research by the Brazilian GDP as percent of Latam. The 2025 estimate extrapolates the growth rate through 2024.
Source: ABI Research; Frost & Sullivan; Telecom Advisory Services analysis

Under such attractive demand conditions, the decisions to be made in terms of the model allocating the 6 GHz spectrum band (European or US-Korean model) could put Brazil on the path to both meet local demand and benefitting from the implicit economies of scale derived from advanced markets as well as increase the opportunity costs of those markets developing first. Additionally, the decision of aligning with a particular model could potentially give Brazil the benefit of developing an export-led industry that could capitalize on foreign demand.

3.9. Enhancing the capability for cellular off-loading

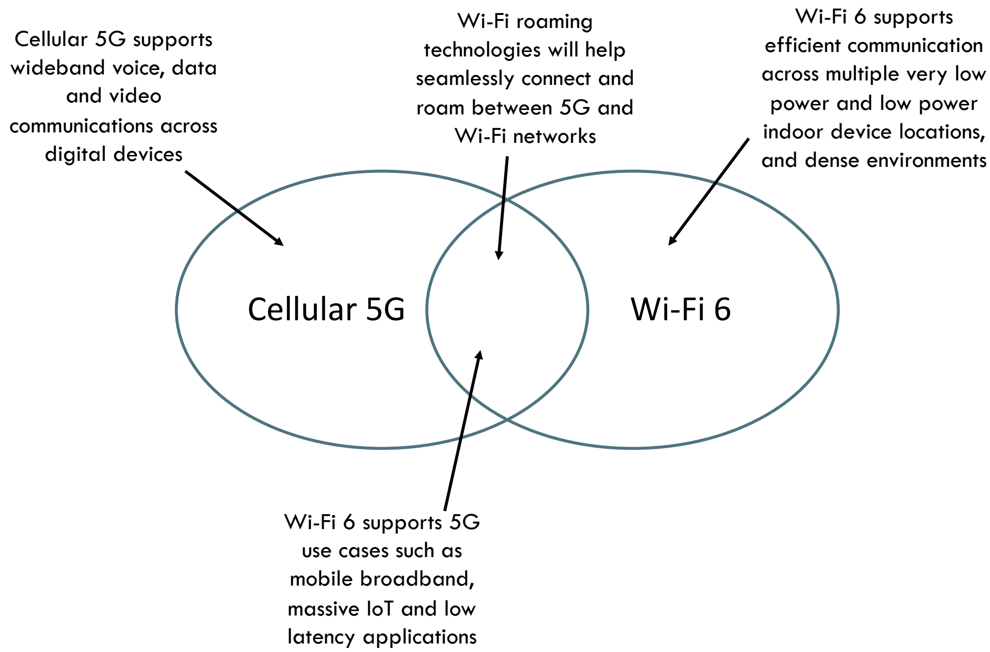
This source of economic value, based on the complementarity between Wi-Fi and cellular networks was initially analyzed by Milgrom et al. (2011), and Cooper (2012), and further estimated in our prior studies (Katz, 2014a, 2014b, 2018a). As posited in earlier studies, the value of cellular off-loading is based on the congestion relief for licensed spectrum owners that comes from the additional spectrum (Bazelon, 2008). In this context, Wi-Fi acts as a complementary technology compensating for the economic limitations of cellular. In the case of spectrum management, unlicensed frequency bands can enhance the effectiveness of devices that use licensed spectrum. For example, Wi-Fi base stations operating in unlicensed bands can enhance the value of cellular networks by allowing wireless devices to switch to hot-spots, thereby reducing the cost of broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi site can reduce their costs of access by turning off their wideband service. They can also gain additional access speed because the transfer rate of Wi-Fi sites is generally faster than that offered by cellular technology.

Wi-Fi allows cellular service providers to decrease the capital and operating expenses required to accommodate exploding data traffic. Brazilian carriers have been deploying Wi-

Fi access points since 2012 to offload part of their traffic[38]. The estimation of savings is predicated on the assumption that, in the absence of additional unlicensed spectrum bands, service providers would have to deploy expensive infrastructure to accommodate the growth in traffic. Thus, the calculation of economic value is based on the portion of capital investments (and potential incremental network operations and maintenance operating expenses) that service providers can avoid when they and consumers shift traffic from cellular networks to Wi-Fi.

While complementarity has been hailed for prior cellular and Wi-Fi technology generations, this feature remains for Wi-Fi 6 and 5G. To begin with, access devices like smartphones and sensors will tend to be equipped with both generations for users and service providers to optimize infrastructure use. This will be critical not only for traffic handling in densely packed environments such as apartment complexes and hospitals, but also to support surveillance cameras, point of sale terminals, environmental sensors and other IoT devices. Complementarity will also manifest itself at homes and enterprises, although this benefit has already been accounted for in the sections above (see figure 3-2).

Figure 3-2. Complementarity of Wi-Fi6 and 5G NR-U



Source: Adapted from Suarez, M. (2020). Unlicensed spectrum access in the 6 GHz band. Presentation to ANATEL

As an example, the vast majority of data consumed on smartphones and other mobile devices flows over Wi-Fi networks, never touching mobile carrier spectrum or infrastructure. In fact, the share of data traffic offloaded via Wi-Fi is expected to increase sharply as mobile technology upgrades from 4G to 5G, since high- bandwidth applications are typically used at home, work and other indoor locations. Cisco projects that 76% of all data traffic on smartphone and other mobile devices will be offloaded onto Wi-Fi in North America by

[38] RCR Wireless (2012). *TIM Brazil to install 10,000 Wi-Fi hot spots in Sao Paulo*, Rio de Janeiro (March 29).

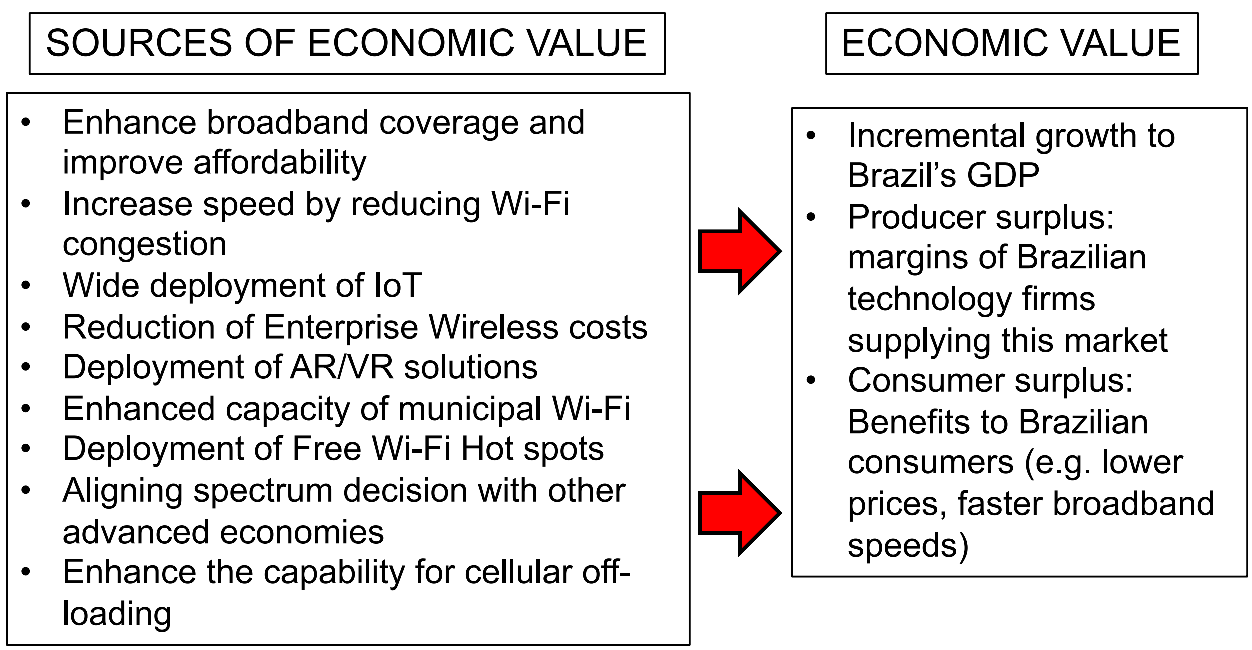
2022[39]. By 2023, 44% of all networked devices in Brazil will be connected via Wi-Fi.[40] As mentioned above, there are 6.2 million public hot-spots and 2.3 free sites in Brazil[41]. The number of public Wi-Fi hot-spots in Brazil will reach 23.8 million[42]. Even cellular providers acknowledge Wi-Fi's central role. For example, Verizon's Executive VP and Consumer Group CEO told an investor conference in January 2020 that between 70% and 75% of mobile device data traffic in the United States is offloaded onto Wi-Fi[43].

Consequently, the economic value of spectrum allocation in the 6 GHz band not only manifests itself in the ability of cellular carriers to reduce capital in 5G deployment by off-loading traffic but, most importantly, to indirectly account for Wi-Fi use in calculating their investment. A related benefit of allocating the 6 GHz to Wi-Fi use results from the ability of the latter to support wireless off-loading without congestion risk.

3.10.A compilation of economic value

Based on the theoretical bases reviewed throughout chapter 3, the approach to be followed for estimating the economic value of allocating spectrum in the 6 GHz band to unlicensed use in Brazil will quantify the effects of the decision (see figure 3-3).

Figure 3-3. Approach to be followed in Estimating Economic Value of 6 GHz decision in Brazil



39 C*isco 2019 VNI Report* at 104.

40 Cisco (2020). *Novo relatório Cisco Annual Internet Report prevê que 5G será responsável por 10% das conexões móveis no mundo em 2023,* p. 2

41 C*isco 2019 VNI Report* at 111.

42 Cisco (2020). *Novo relatório Cisco Annual Internet Report prevê que 5G será responsável por 10% das conexões móveis no mundo em 2023,* p. 4

43 Verizon, Citi 2020 Global TMT West Conference, Webcast (Jan. 7, 2020). Available: https://www.verizon.com/about/investors/citi- 2020-global-tmt-west-conference.

Source: Telecom Advisory Services

A final clarification with regards to methodology: We consider that cumulating GDP effect and producer surplus on equipment sales is reasonable given that the impact on GDP is fundamentally attributed in our models based on historical data to speed increase and not to producer surplus driven by equipment sales triggered by new unlicensed spectrum allocation. On the other hand, CAPEX savings triggered by wireless carriers offloading traffic to Wi-Fi access point has been occurring for a while and could be included in the GDP model estimates. Therefore, in this particular case, the effect derived from CAPEX savings will be excluded from totals to avoid double counting.

4. ENHANCE BROADBAND COVERAGE AND IMPROVE AFFORDABILITY

The latest statistics for Brazil indicate a 2019 fixed broadband penetration of 46.35% (or 32,914,496 connections for 71,014,575 households)[44]. Based on the growth rate assumed by the National Broadband Plan, an extrapolation to 2030 indicates that penetration will reach 61.16%. In addition to conventional telecommunications carriers, Wireless ISPs (WISPs) can fulfill a critical role in addressing the broadband supply and demand gap.

4.1. The current situation in Brazil

The Brazilian WISPs cover approximately 12 million households (33%). There are 3,450 Brazilian WISPs[45] registered in ANATEL with sizes ranging between 50 and 76,000 lines. In total, the Brazilian WISPs operate 1,962,163 wireless connections in 2020. Of these, 1,810,272 are Wi-Fi based and 151,891 rely either on WiMAX or other wireless technologies[46]. Most lines supplied by WISPs are in the lower speeds range: 24.9% are under 2 Mbps, and 57% are between 2 Mbps and 12 Mbps (see table 4-1).

Table 4-1. Brazil: WISP Lines (2020)

	Wi-Fi based		Not Wi-Fi (*)		Total	
	N	%	N	%	N	%
<512 Kbps	57,660	3.19%	5,905	3.89%	63,565	3.24%
512 Kbps-2 Mbps	367,467	20.30%	57,569	37.90%	425,036	21.66%
2 Mbps-12 Mbps	1,043,347	57.63%	76,010	50.04%	1,119,357	57.05%
12 Mbps – 34 Mbps	267,827	14.79%	7,969	5.25%	275,796	14.06%
>34 Mbps	73,971	4.09%	4,439	2.92%	78,410	4.00%
Total	1,810,272	100.00%	151,891	100.00%	1,962,163	100.00%

(*) WiMax, FWA, and other technologies.
Source: ANATEL. Plano de Dados Abertos da Anatel, available at: https://www.anatel.gov.br/paineis/acessos/banda-larga-fixa; *Telecom Advisory Services analysis*

WISPs tend to serve predominantly lower income groups households: according the CeTIC.br survey, 82.43% of WISP customers belong to the C, D, and E strata (see table 4-2).

[44] ANATEL. Plano de Dados Abertos da Anatel, available at: https://www.anatel.gov.br/paineis/acessos/banda-larga-fixa

[45] The difference between this number extracted from the ANATEL files and the often-quoted 10,000 WISPs is due to some very small non-registered players (WISPs are not required to have a license in Brazil) and the fact that the above estimate does not double count WISPs serving more than one municipality.

[46] Analysis of ANATEL. Op. cit.

Table 4-2. Brazil: Fixed broadband statistical distribution by socio-economic level (2019)

Socioeconomic level	Total Fixed Broadband	WISP	Difference
A	3.02%	0.23%	-2.79%
B	26.14%	17.34%	-8.80%
C	53.81%	60.90%	7.08%
DE	17.03%	21.53%	4.50%

Source: CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019. Telecom Advisory Services analysis

As a result of the lower income population concentration, WISP Wi-Fi lines are frequently shared among neighbors. According to the Cetic.Br survey[47], in 2019 12.83 % of households in Brazil access broadband by sharing a fixed broadband connection with a neighbor (see table 4-3).

Table 4-3. Brazil: Connection sharing of fixed broadband (2019)

Social segment	Sharing connections	No sharing	Fixed broadband adoption	Households	Sharing (% households)	Sharing (% FBB connections)
A	42,014	968,626	936,312	1,023,546	4.10%	4.49%
B	1,013,344	8,789,229	8,094,498	10,362,204	9.78%	12.52%
C	4,801,714	21,801,264	16,665,042	33,317,611	14.41%	28.81%
D+E	3,255,980	9,692,216	5,272,584	26,311,214	12.37%	61.75%
Total	9,113,052	41,251,335	30,968,436	71,014,575	12.83%	29.43%

Source: CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019

This number had increased from 8.10% in 2015. Considering that WISPs serve primarily the most disadvantaged population, rather than relying on the aggregate sharing factor for fixed broadband of 12.83%, we rely for the following analysis on the sharing ratio corresponding to the C, D, and E segments. Accordingly, we estimate that 36.73% of Brazilian households that purchase a WISP-based broadband connection in the C, D and E segments share the line with their neighbor(s). This means that for every line deployed by a WISP, an additional 0.36 lines need to be added[48].

Based on interviews with a WISP association[49], the total number of fixed wireless lines is declining due to a gradual migration of fixed wireless lines to fiber optics in the access

[47] CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019/2018/2017/2016/2015

[48] We believe this number might be conservative because interviews with the WISP association indicate that for every connection installed, up to 2 households would share it.

[49] Interview of Alex Jucius, General Director, Associaçao NEO.

portion of the networks[50]. On the other hand, considering the evolution of the sharing ratio since 2015, we forecast this value though 2030 to be increasing from the 2019 value of 36.73% to 83.01%. These two contradictory tendencies yield the future evolution of households served by WISPs going forward (see table 4-4).

Table 4-4. Brazil: WISP Lines (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Wi-Fi based	1,810,272	1,694,747	1,586,595	1,485,345	1,390,556	1,301,816	1,218,739	1,140,964	1,068,152	999,987	936,171
Non Wi-Fi based	151,891	142,198	133,123	124,628	116,675	109,229	102,258	95,733	89,623	83,904	78,550
Total	1,962,163	1,836,945	1,719,718	1,609,973	1,507,231	1,411,045	1,320,997	1,236,697	1,157,775	1,083,891	1,014,721
Shared ratio	40.95%	45.16%	49.38%	53.59%	57.80%	62.00%	66.21%	70.41%	74.61%	78.81%	83.01%
Total	2,765,669	2,666,509	2,568,915	2,472,758	2,378,411	2,285,893	2,195,629	2,107,455	2,021,591	1,938,105	1,857,041

Sources: ANATEL; Cetic.br; Telecom Advisory Services analysis.

As indicated in table 4-4, despite the increase in sharing ratio, the gradual decline in fixed wireless connections yields a decreasing number of households served by Wi-Fi and non-Wi-Fi technologies, devolving from 2.76 million to 1.86 million.

4.2. Impact of 6 GHz on consumer surplus of WISP customers

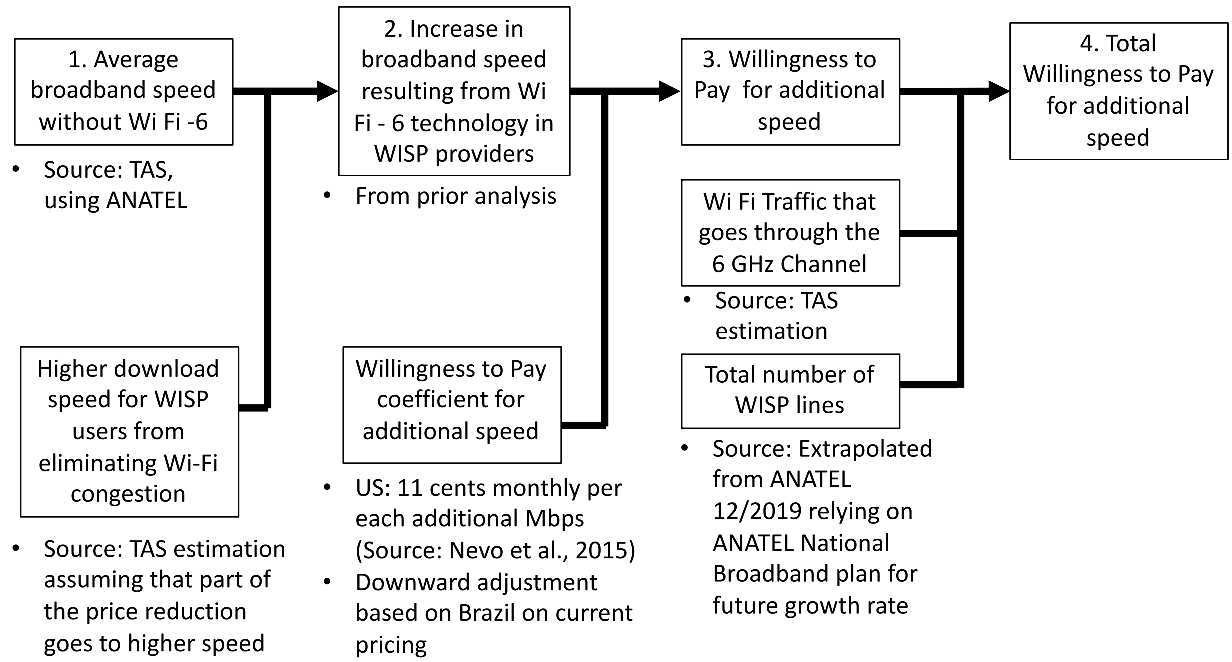
As reviewed in figure 3-1 of the theoretical framework chapter, the 6 GHz decision would have an impact in two areas of economic value of WISPs: (i) growing consumer surplus of existing customers as a result of faster broadband service, and (ii) increasing affordability and, consequently, penetration of broadband, which in turn impacts the GDP. Each area will be reviewed in turn.

Increasing consumer surplus due to enhanced base station performance

When WISPs have the opportunity of relying on spectrum in the 6 GHz band, the consumer surplus for their subscribers is generated by an improvement in broadband speed as Wi-Fi congestion is eliminated in the networks. In other words, the higher speed for the lines affected by the technology migration is multiplied by the willingness to pay (see figure 4-1).

[50] See also ABRINT (2018). *Plano de modernização e expansão de acessos com implantação de redes FTTH*. and NEO interview.

Figure 4-1. Methodology to estimate consumer surplus as a result of faster download sped in WISP connections



Source: Telecom Advisory Services

The starting point of this estimate is to calculate the difference in broadband speed yielded by the 6 GHz spectrum. The multiplication of the speed increase by the willingness to pay (WTP) coefficient for incremental broadband speed yields an enhancement of consumer surplus by line. Finally, the WTP per line is multiplied by the number of WISP lines (see table 4-5).

Table 4-5. Consumer surplus due to WISP user speed increase (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Average Download Speed	9.54	9.54	9.54	9.54	9.54	9.54	9.54	9.54	9.54	9.54	9.54
(2) New Average Download Speed	9.54	10.83	12.29	13.95	15.83	17.97	20.39	23.14	26.27	29.81	33.83
(3) Demand for average download speed	70.16	70.16	70.16	70.16	70.16	70.16	70.16	70.16	70.16	70.16	70.16
(4) New Demand for average download speed	70.16	72.93	75.69	78.46	81.23	84.00	86.77	89.54	92.31	95.08	97.85
(5) Additional Monthly Consumer surplus	$0.00	$2.77	$5.54	$8.31	$11.08	$13.85	$16.62	$19.39	$22.16	$24.92	$27.69
(6) Additional Yearly Consumer Surplus	$0.00	$33.23	$66.47	$99.70	$132.93	$166.17	$199.40	$232.63	$265.87	$299.10	$332.33
(7) WISP Connections (Millions)	2.236	1.962	1.837	1.720	1.610	1.507	1.411	1.321	1.237	1.158	1.084
(8) Traffic through 6 GHz Band	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(9) Impact (USD Millions)	$0	$5	$18	$39	$64	$94	$127	$161	$197	$234	$270
(10) Impact (USD Billions)	0.000	0.005	0.018	0.039	0.064	0.094	0.127	0.161	0.197	0.234	0.270

Sources: Telecom Advisory Services analysis.

Total 2020-2030 cumulative consumer surplus impact resulting from increasing broadband speed by reducing Wi-Fi congestion for WISP users amounts to US$1.209 billion.

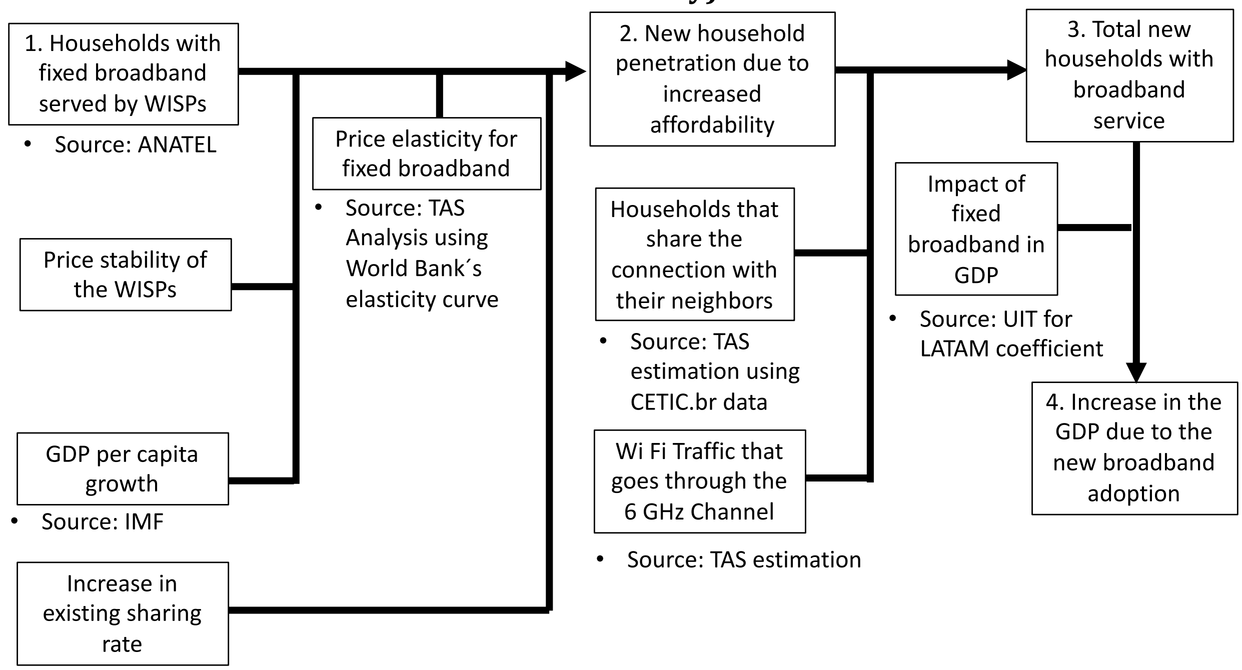
4.3. Impact on GDP by increasing affordability and penetration of broadband from WISPs

The objective in this case is to estimate the impact on GDP of the change in broadband affordability and consequential broadband penetration within WISPs. To start with, the 6 GHz allocation to unlicensed use will improve the number of households being served per WISP access point. In theory, given the conventional economies of scale in telecommunications, the unit cost to serve a higher number of subscribers from a single point would reduce the unit OPEX. Furthermore, this reduction could be partially neutralized by the amortization of CAPEX to migrate the electronics to the new standard[51]. For conservative purposes, we assume that broadband service prices from Brazilian WISPs would not change from current levels. This was supported by interviews with the Brazilian WISP association[52]. However, considering that the GDP per capita would increase in the future (per the IMF forecast), the overall affordability of service at real prices will be higher. This will allow consumers who have argued that pricing represented a barrier to adoption to acquire broadband service. In addition, the higher performance of Wi-Fi 6 will allow an increase of sharing households, which should be added to the new adopters. A higher broadband penetration will in turn have an impact on the Brazilian GDP. Figure 4-2 presents the methodology followed to develop this estimate.

[51] On a side note, the experience of United States WISPs indicates that, if the spectrum allocated is adjacent to the 5 GHz bands originally used, the existing SDR equipment can be converted for use in the newly allowed band and can be adjusted to work in at least the lower band of 6 GHz. Of course, the use of current equipment may be subject to standards and protocols as well as an AFC that may not be possible with current equipment. Its "International" designation may also impact the availability for use.

[52] Interview of Alex Jucius, General Director, Associaçao NEO.

Figure 4-2. Methodology to estimate GDP impact of increasing broadband affordability)



Source: Telecom Advisory Services

The starting point is the number of households served by Brazilian WISPs as depicted in table 4-4, devolving from 1,962,163 in 2020 to 1,014,721 in 2030 (with a high concentration of the latter number in rural areas). By assuming price stability of broadband services and accounting for the GDP growth forecast from the IMF, affordability increases at 3.60% per year. It should be acknowledged however that not all WISPs will migrate to Wi-Fi 6 immediately: we assume that 7.5% of lines will be impacted in 2021, reaching 75% in 2030. This yields the first effect of incremental lines due to enhanced affordability. The second effect is the increase in line sharing of existing lines because, with no congestion, sharing becomes more feasible (see table 4-6).

Table 4-6. Brazil: New WISP lines resulting from increased affordability

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) New WISP adoption after price decrease (% households)	2.74	2.89	2.69	2.51	2.34	2.18	2.03	1.89	1.76	1.64	1.52
(2) Traffic through 6 GHz Band	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(3) Increase in WISP connections due to lower prices (households that buy the service)	0	18,283	34,391	48,502	60,782	71,392	80,480	88,183	94,631	99,942	104,229
(4) Sharing %	40.95%	45.16%	49.38%	53.59%	57.80%	62.00%	66.21%	70.41%	74.61%	78.81%	83.01%
(5) Increase in WISP connections due to lower prices (considering households that share the connection)	0	26,540	51,372	74,492	95,913	115,659	133,765	150,274	165,237	178,709	190,748
(6) New users due to higher sharing rate	0	5,808	21,743	45,788	76,187	111,418	150,166	191,302	233,861	277,024	320,101

Sources: Telecom Advisory Services analysis.

The cumulation of both effects drives an increase in broadband penetration exclusively due to 6 GHz effect on Brazilian WISPs: up to .67% in 2030. Based on the coefficient of impact of fixed broadband on GDP calculated by the authors in research for the International Telecommunication Union[53], the total GDP impact is estimated (see table 4-7).

Table 4-7. Brazil: GDP contribution of New WISP lines resulting from increased affordability

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(7) Increase in national broadband penetration	0.00%	0.04%	0.10%	0.17%	0.24%	0.31%	0.38%	0.46%	0.53%	0.61%	0.67%
(8) Impact of fixed broadband adoption in GDP	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745
(9) Increase in the GDP due to the new broadband adaptation (% GDP)	0.00%	0.01%	0.03%	0.05%	0.07%	0.08%	0.10%	0.12%	0.14%	0.16%	0.17%
(10) GDP (US$ Billion)	$ 1,893	$ 1,988	$ 2,084	$ 2,189	$ 2,296	$ 2,408	$ 2,526	$ 2,650	$ 2,780	$ 2,916	$ 3,058
(11) Total impact in GDP (US$ Billion)	$ 0.000	$ 0.286	$ 0.648	$ 1.066	$ 1.516	$ 1.955	$ 2.539	$ 3.172	$ 3.849	$ 4.565	$ 5.315

Sources: Telecom Advisory Services analysis.

In addition, the potential extension of point to point backhauling could increase the WISP coverage in rural areas. According Cetic.br survey, there are 511,881 rural households without broadband that do not acquire service because of lack of coverage. If we assume that 6 GHz spectrum could allow WISPs to extend their coverage into the rural areas, it could yield at least an increase equivalent to 24.57% of the unserved households (the current penetration of rural households), which would result in 125,884 homes (or 0.18% of incremental penetration in Brazil). However, considering that some equipment issues still need to be addressed (e.g. weatherproofing), this impact will not be included in the total effect.

In summary, the total cumulative impact on the GDP resulting from increased broadband penetration due to enhanced affordability and sharing is US$24.91 billion.

[53] Katz, R. and Callorda, F. (2018). *The economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the Americas*. Geneva: International Telecommunications Union, p. 10

5. INCREASE SPEED BY REDUCING Wi-Fi CONGESTION

As in the case of WISPs, the value to be generated by the increase in average wireless speed resulting from allocating spectrum in the 6 GHz band for all Brazilian broadband households relying on Wi-Fi connectivity in the premise translates into a contribution to the GDP and an increase in consumer surplus.

5.1. Current broadband speeds in Brazil and the importance of Wi-Fi congestion

ANATEL reports that out of the 32,994,902 broadband lines (April 2020), 15,574,719 (or 47%) are in excess of 34 Mbps. Additionally, CISCO in its Visual Networking Index reports that 2.14% of all fixed broadband lines in Brazil are in excess of 100 Mbps. Assuming a normal distribution of lines higher than 100 Mbps would indicate that 0.89% of all lines are in excess of 150 Mbps: 293,654 connections. This estimate is fairly reasonable considering the number of plans in excess of 100 Mbps currently offered by various operators (see table 5-1).

Table 5-1. Brazil: Fixed Broadband Plans in excess of 100 Mbps

Carrier	Features	Plan1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
Claro	Speed	120	240	500			
	Price	$ 139.99	$ 169.99	$ 429.99			
	Geography	Various zones					
Oi	Speed	200	400				
	Price	$ 119.90	$ 169.90				
	Geography	Rio de Janeiro, Belo Horizonte, Salvador, Fortaleza, Recife, Goiania, Brasilia, Porto Alegre, Curitiba					
TIM	Speed	150	400				
	Price	$ 125.00	$ 150.00				
	Geography	Rio de Janeiro, São Paulo, Minas Gerais, Amazonas, Bahia, Goiás and Pernambuco					
SERCOMTEL	Speed	100	150	200	250	300	500
	Price	$ 174.90	$ 204.90	$ 242.90	$ 279.90	$ 309.90	$ 459.90
	Geography	Parana					
Algar Telecom	Speed	100	200	300			
	Price	$ 139.25	$ 149.93	$ 171.27			
	Geography	Various zones					
Brisanet	Speed	100	200				
	Price	$ 83.00	$ 99.00				
	Geography	Various zones					
SBS Net	Speed	125	200	250	300	350	450
	Price	$ 69.90	$ 99.90	109.9	149.9	189.9	249.9
	Geography	Minas Gerais – Sao Paulo					
Cabo Telecom	Speed	150	250	350			
	Price	$ 94.90	$ 137.90	185.9			
	Geography	Rio Grande do Norte - Paraiba					
Unifique Telecomunicações	Speed	100	150	200	300	400	500
	Price	$ 109.90	$ 139.90	169.9	229.9	289.9	349.9
	Geography	Santa Catarina					

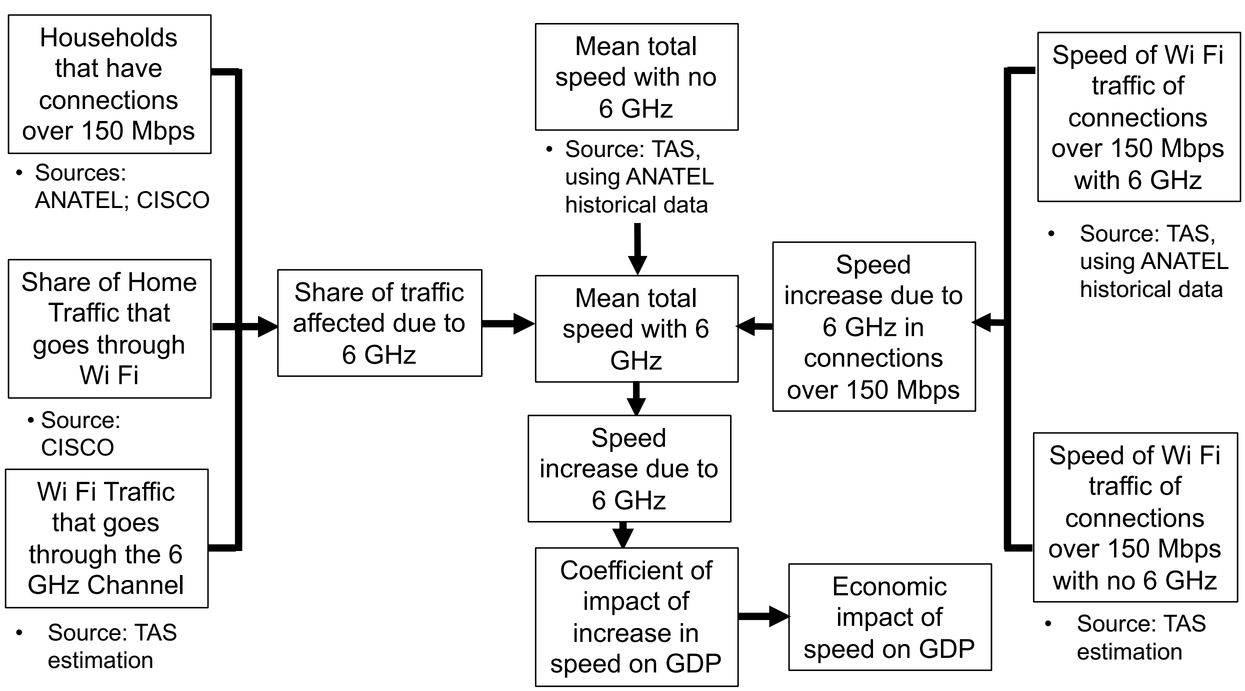
Source: Compiled by Telecom Advisory Services from operator websites

As explained in chapter 3, if a household acquires a 150 Mbps fixed broadband line, the router becomes a choke point in the network, and the speed experienced at the device level will be well below that delivered by the fixed network. While given the statistics review above, the number of lines undergoing a potential bottleneck at the router level in Brazil is low, a projection over the next five years indicates that by 2025 this will increase to 3,099,332 lines (or 7.02% of 44,150,024 total lines). In other words, given the increase in download speed of fixed broadband lines, if Wi-Fi performance is not improved by opening additional spectrum, the in-premise equipment becomes a network bottleneck, and the speed experienced by a consumer at home will not be equivalent to that delivered by fixed networks. Conversely, by increasing the spectrum in the 6 GHz allocated to Wi-Fi, the speed will increase with the consequent economic effect.

5.2. Contribution to GDP by reducing Wi-Fi congestion

The objective is to estimate the impact on GDP of the future change in average broadband speed resulting from the improvement in speed for those households undergoing a Wi-Fi bottleneck (those purchasing fixed broadband plan in excess of 150 Mbps now and in the future). As explained above, despite the broadband capacity reaching the house, these users would undergo a "bottleneck" in network performance as a result of spectrum-limited CPE (e.g. Wi-Fi router). Figure 5-1presents the methodology followed to develop the estimate.

Figure 5-1. Methodology to estimate GDP impact of reducing Wi-Fi congestion



Source: Telecom Advisory Services

The starting point of the methodology is to estimate the number of households in Brazil that have a connection over 150 Mbps that would undergo a Wi-Fi congestion problem as a result of routers relying on the .4 GHz and 5.8 GHz bands. Based on the current 2.4 GHz and 5 GHz allocation, dual router performance currently reaches 266.50 Mbps, which results from assuming an even split of traffic between the 2.4 GHz band (at 173 Mbps) and 5 GHz band (at 360 Mbps)[54]. The assignment of spectrum in the 6 GHz band would increase the average router capacity and reduce congestion, and with that, the average broadband speed would increase[55]. This calculation assumes that 5% of the traffic will be routed through the 6 GHz band in 2021, reaching 75% in 2030.

Because not all households subscribe to a fixed broadband connection that undergoes a bottleneck at the CPE, we only consider in our analysis Brazilian households that have a connection in excess of 150 Mbps (which when forecasting 2021 from the ANATEL data we assume to be 1.05% in 2021, it will increase to 44% by 2030). In addition, not all traffic undergoes a router bottleneck, because a portion of it is being distributed through ethernet cabling, thereby avoiding Wi-Fi. This portion is relatively stable, starting at 60.54% and reaching 61.63% at the end of the time period. Finally, it is assumed that in 2021, 7.50% of Wi-Fi traffic is distributed through the router's 6 GHz, reaching 75% by 2030 (see table 5-1).

Table 5-1. Brazil: Estimation of fixed broadband connections affected by 6 GHz decision

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Households that have connections over 150 Mbps (%)	0.89%	1.05%	2.22%	4.37%	5.56%	7.02%	8.79%	13.52%	20.35%	30.12%	44.00%
(2) Share of Home Traffic that goes through Wi Fi (%)	60.54%	60.65%	60.76%	60.87%	60.98%	61.08%	61.19%	61.30%	61.41%	61.52%	61.63%
(3) Traffic through the 6 GHz Channel (%)	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(4) Share of traffic affected due to 6 GHz (%)	0.00%	0.05%	0.20%	0.60%	1.02%	1.61%	2.42%	4.35%	7.50%	12.51%	20.34%

Sources: ANATEL; Cisco Virtual Networking Index

This allocation will have an impact on Wi-Fi download speed of an incremental 200 Mbps in 2021, reaching 650 Mbps by 2030 (see table 5-2).

[54] See RAND study, table 5.2, p. 22, Scenario 1.

[55] An important clarification: while this analysis is conducted for a router's total throughput, it is important to establish that the key driver is the perceived performance of a single user, which is less than 468.00 Mbps. Through the use of multiple bands and spatial streams, routers today commonly today have total throughput capabilities well in excess of the speeds they can enable for individual devices. For example, a high-end 802.11ax device can, in theory, handle total throughput of 4.8 Gbps. The addition of 1,200 MHz in the 6 GHz band has an impact at the device level that could be higher than the total router throughput.

Table 5-2. Brazil: Estimation of fixed broadband speed in connections affected by 6 GHz decision

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(5) Speed of Wi Fi traffic of connections over 150 Mbps (no 6 GHz) (Mbps)	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00
(6) Speed of Wi Fi traffic of connections over 150 Mbps (with 6 GHz) (Mbps)	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00	750.00	800.00
(7) Speed increase due to 6 GHz (Mbps)	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00

Sources: Telecom Advisory Services analysis

Having removed the spectrum bottleneck, the forecast of average fixed broadband household speed tends to grow unencumbered. This results in a speed increase of 0.10 Mbps for the average broadband connection in 2021, reaching 132.18 Mbps in 2030.

Table 5-3. Brazil: Increase in Speed resulting from 6 GHz allocation

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(9) Mean speed with no 6 GHz (Mbps)	43.26	48.27	54.43	66.04	77.32	92.58	108.54	126.43	152.08	189.17	243.00
(10) Mean speed with 6 GHz (Mbps)	43.26	48.36	54.94	67.83	80.88	99.01	119.42	148.19	193.32	264.20	375.18
(11) Difference	0.00	0.10	0.51	1.79	3.56	6.44	10.89	21.76	41.24	75.03	132.18

Sources: Telecom Advisory Services analysis

This increase is used to calculate the impact on GDP. The economic impact coefficient of incremental speed was calculated through an econometric model based on a historical data panel constructed for 49 countries with average data speeds higher than 40 Mbps for a time series between 2008 and 2019.[56] The data comprised 575 observations of quarterly data for:

- Average fixed broadband download speed[57](source: Speedtest Global Index)
- Gross Domestic Product (at current prices US$) (source: IMF)[58]
- Population (source: IMF)
- Fixed broadband adoption (percent of households with fixed broadband with a speed of at least 256 kbps) (source: International Telecommunication Union)
- Controls for country and time periods

[56] Of the 176 countries published now by Speedtest, we could only use a times series to run the model, which limited the number of countries to 159. Of those, we only run the model for those countries that exhibited an average fixed broadband speed higher than 40 Mbps at any point in time.
[57] The data panel on the Speedtest Global Index covers 159 countries.
[58] The models used GDP at current prices in USD because the objective is to measure the impact of GDP in USD, without considering PPP as a deflator.

The model includes:

- a control for the previous quarter's GDP, to isolate the inertial effect of country growth
- download speed lagged by four quarters (1 year) to avoid a reversed causality effect
- changes in employment, to isolate the effect on GDP of the evolution of the labor market
- the country's investment rate (% of GDP) lagged by four quarters (1 year) to isolate the effect of investment on GDP
- the fixed broadband penetration rate to separate the broadband adoption effect from the speed effect

$$lnGDP_{it} = \beta_0 + \beta_1 lnGDP_{it-1} + \beta_2 lnDownload\ Speed_{it-4} + \beta_3 lnEmployment_{it} + \beta_4 lnInvestment\ Rate_{i} + \beta_5 lnFixed\ Broadband\ Adoption_{it} + \delta Country_i + \vartheta Time_t + \mu_{it}$$

We believe the inclusion of the country's investment rate as percent of GDP lagged by four quarters and broadband penetration rate and the model specification run on a worldwide panel help correct for any omitted variable bias. For example, the inclusion of fixed broadband adoption, which is correlated with broadband speed, allows for capturing a portion of the GDP impact that otherwise would be incorrectly attributed to broadband speed. With this in mind, the model yields the following results: every doubling of fixed broadband speed yields 0.73% in GDP growth (see Table 5-4).

Table 5-4. Impact of Fixed Broadband Download Speed on GDP

Impact on ln GDP	Download Speed higher than 40 Mbps
Ln Download Speed $_{t-4}$	0.00730 (0.00211) ***
Ln Employment $_{t}$	0.00458 (0.00165) ***
Ln Investment $_{t-4}$	-0.00085 (0.00481)
Control for Fixed Broadband adoption	0.00284 (0.00414)
Control for growth of previous GDP	0.99454 *** (0.00168)
Country Fixed Effect	Yes
Time Fixed Effect	Yes
Number of countries	49
Observations	575
R-Square	0.9438

***, **, * significant at 1%, 5% and 10% critical value respectively.
Source: Telecom Advisory Services analysis

By applying the coefficient of GDP impact of 0.73% for a 100% increase in speed, we estimate the overall GDP impact resulting from an increase in speed as a result of the allocation of the 6 GHz[59].

[59] It is important to note that, while the fixed broadband adoption coefficient is not statistically significant, this is due to the fact that the countries included in the sample have extremely high fixed broadband

Table 5-5. Brazil: Estimation of economic impact by reducing Wi-Fi congestion

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(12) Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%
(13) Increase in GDP (%)	0.00%	0.00%	0.01%	0.02%	0.03%	0.05%	0.07%	0.13%	0.20%	0.29%	0.40%
(14) Brazil GDP Billions US$	$1,717	$1,778	$1,842	$1,909	$1,977	$2,049	$2,122	$2,199	$2,278	$2,360	$2,445
(15) Impact (US$ Billions)	$0.000	$0.026	$0.125	$0.378	$0.665	$1.040	$1.554	$2.762	$4.509	$6.833	$9.708

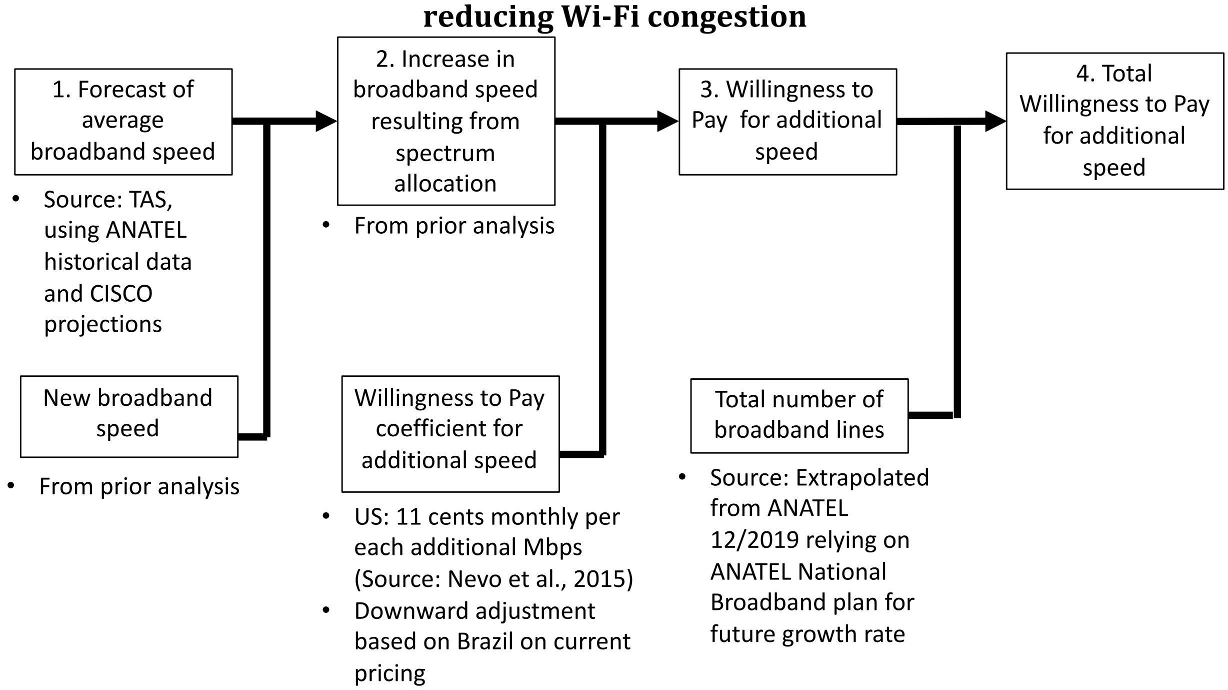
Sources: ANATEL; Cisco Virtual Networking Index

Total GDP contribution of the 6 GHz band allocation between 2021 and 2030 will reach US$27.60 billion.

5.3. Contribution to consumer surplus by reducing Wi-Fi congestion

As shown above, the allocation of the 6 GHz band to unlicensed use will have a net positive effect in terms of increased router throughput and therefore, average broadband speed. To reiterate, the consumer surplus to be estimated in this case should not be part of the GDP contribution but can be considered as part of the aggregate economic value. The key objective is to estimate the increase in consumers' willingness to pay derived from the acceleration in average broadband speeds. The approach to estimate consumer surplus relies on the same calculations presented above in terms of the increase in Wi-Fi speed but factors them in terms of incremental wireless speed and the consequent impact on willingness to pay (see Figure 5-2).

Figure 5-2. Methodology to estimate Consumer Surplus contribution resulting from reducing Wi-Fi congestion



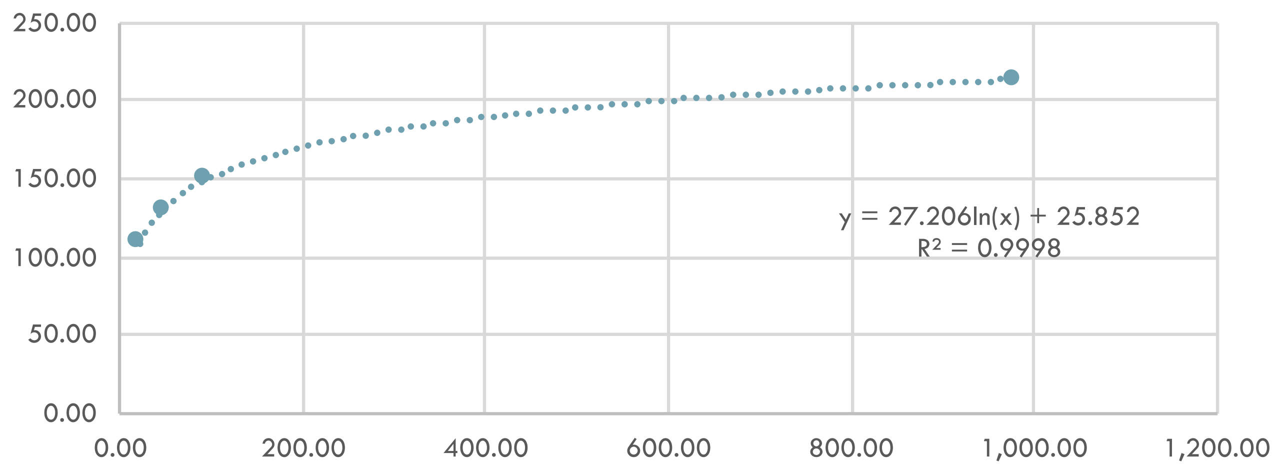
Source: Telecom Advisory Services

penetration; for these countries, the primary economic impact is not on adoption (e.g. late adopters will have less impact) but on speed.

As calculated based on the broadband speed, the expected average broadband speed in 2021 in Brazil will be 48.27 Mbps. By addressing the bottleneck for users acquiring service in excess of 150 Mbps, average speed will increase to 375.18 Mbps in 2030, which results in a net increase in speed of 132.18 Mbps (calculated in table 5-3 in the methodology for estimating the return to speed in section 5.1).

The next step is to estimate what consumers would be willing to pay for the additional speed. Given the lack of Brazilian willingness to pay data, the analysis conducted for this study relies on the data specifying the relationship between speed and consumer surplus generated in the Nevo et al. (2016) study for the United States.[60] This research provides empirical evidence stating that consumers' willingness to pay (WTP) to improve broadband speed by 1 Mbps ranges from nearly zero to just over US $5.00. The range is determined by heterogeneity in WTP, although the average value is US $2.02, and the median is US $2.48. Furthermore, the study also indicates that the higher speed does indeed generate substantial surplus. However, due to a declining marginal value of speed, speeds of more than 10 times those offered by the typical broadband plans imply only 1.5 times the surplus.[61] The data provided in the Nevo et al. (2016) study allows estimating a log curve depicting the relationship between willingness to pay and speed (see Graphic 5-1).

Graphic 5-1. Log Curve of relationship between broadband speed and willingness to pay (based on Nevo et al., 2016)



Note: Based on data points of table VII and table VI of Nevo et al., 2016.
Source: Nevo et al.(2016); Telecom Advisory Services analysis

[60] Nevo, A., Turner, J., and Williams, J. (Mar. 2016). "Usage-based pricing and demand for residential broadband", *Econometrica*, vol. 84, No.2, p. 441-443.
[61] This finding is consistent with the evidence provided in Liu et al. (2017), who found that the shape of households' valuation of broadband speed is concave. "Households are willing to pay about $2.34 per Mbps ($14 total) monthly to increase bandwidth from 4 Mbps to 10 Mbps, $1.57 per Mbps ($24) to increase from 10 to 25 Mbps, and only $0.02 per Mbps ($19) for an increase from 100 Mbps to 1000 Mbps."

According to the data of the Graphic 5-1, an increase in speed from 92.50 Mbps to 977.90 Mbps (ten times) increases willingness to pay from $149.90 to $212.90 (close to 1.5 times). The equation linking speed to consumer surplus was then used to estimate the value to be derived by faster download speeds enabled by allocation of the 6 GHz band to unlicensed use. For this purpose, the difference between average download speed enabled by 6 GHz frequencies and current average download speed as increased annually at the current growth rate was multiplied by the coefficient of the log curve as depicted in the Graphic 5-1. This results in an additional $1.10 per month (or $13.22 per year). This curve was downward adjusted by a factor of 80.43% to account for pricing differences between the United States and Brazil. Estimating, based on ANATEL and CISCO data, that by 2030 the number of broadband subscribers will rise to 46.28 million, the total consumer surplus is calculated.

Under these two assumptions the consumer surplus impact would be $18 million in 2021 (see results and calculations in Table 5-6).

Table 5-6. Consumer Surplus from 6 GHz unlicensed (2021)

	Data	Source
(1) Average 2021Fixed Broadband Download Speed (at end user device)	48.27	Return to speed analysis
(3) New Average Fixed Broadband Download Speed	48.36	Return to speed analysis
(4) Demand for average download speed	$ 105.62	Equation in graphic 3-2
(5) New demand for average download speed	$ 195.67	Equation in graphic 3-2
(6) Additional Monthly Consumer surplus	$ 0.04	(4 – 3)
(7) Additional Yearly Consumer Surplus	$ 0.52	(5) * 12
(8) Fixed Broadband Connections (Millions)	35.431	Estimation using FCC historical data
(9) Impact (US$ Millions)	$ 18	(7)*(8)

Source: Telecom Advisory Services analysis

As in the case of the return to speed analyzed above, the annual consumer surplus generated by faster Wi-Fi will also be influenced by the same trends that evolve after 2022. These trends will affect the annual contribution to faster speeds resulting from the 6 GHz allocation as follows (see Table 3-9).

Table 3-9. Consumer Surplus from 6 GHz unlicensed (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Average Download Speed	43.26	48.27	54.43	66.04	77.32	92.58	108.54	126.43	152.08	189.17	243.00
(2) New Average Download Speed	43.26	48.36	54.94	67.83	80.88	99.01	119.42	148.19	193.32	264.20	375.18
(3) Demand for average download speed	103.23	105.62	108.25	112.48	115.94	119.88	123.36	126.70	130.74	135.51	140.99
(4) New Demand for average download speed	103.23	105.67	108.46	113.07	116.92	121.35	125.45	130.17	135.99	142.82	150.50
(5) Additional Monthly Consumer surplus	$0.00	$0.04	$0.20	$0.59	$0.98	$1.47	$2.09	$3.47	$5.25	$7.31	$9.50
(6) Additional Yearly Consumer Surplus	$0.00	$0.52	$2.43	$7.04	$11.82	$17.65	$25.10	$41.70	$63.00	$87.72	$114.05
(7) Fixed Broadband Connections (Millions)	34.073	35.431	37.023	38.884	41.042	44.042	44.483	44.928	45.377	45.831	46.289
(8) Impact (USD Millions)	$0	$18	$90	$274	$485	$777	$1,117	$1,873	$2,859	$4,020	$5,279

Source: ANATEL; Nevo et al. (2016); Telecom Advisory Services analysis

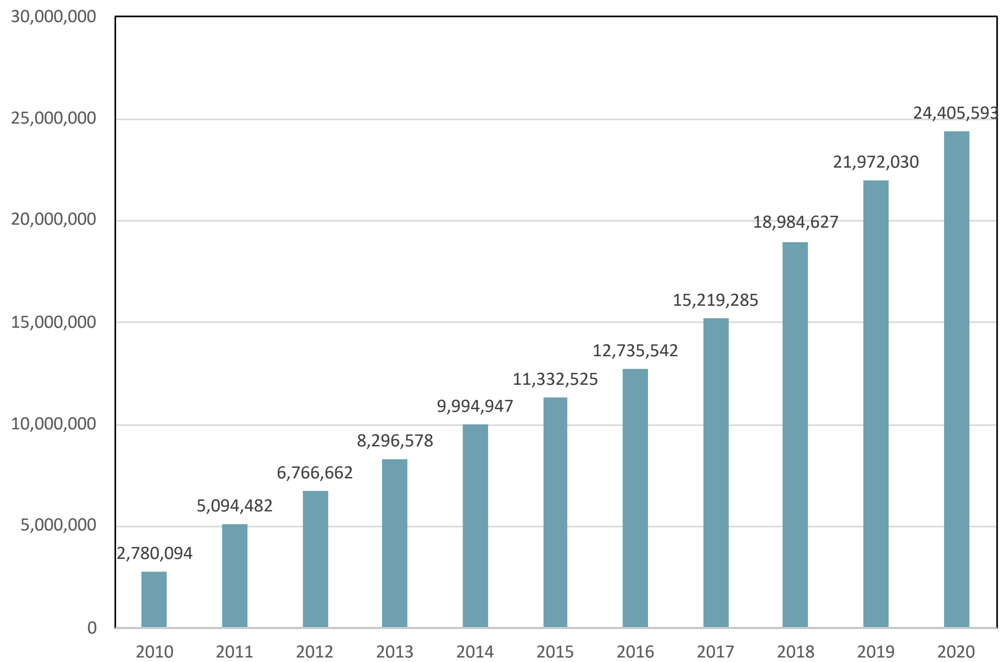
The increase of the average household in consumer surplus evolves from US$0.52 in 2021 to US$114.05 in 2030 (the households with bottleneck will have an increase higher than that, but the households with no bottleneck will have $0); this is the value multiplied by the total number of connections. Total consumer surplus associated with the 6 GHz band between 2021 and 2030 will reach $16.79 billion.

6. WIDE DEPLOYMENT OF INTERNET OF THINGS

6.1. The critical importance of IoT in Brazil

Considering, as mentioned above, that IoT devices have been deployed in Brazil for a number of years, the economic value estimation of "broader" deployment resulting from the combination of a significant amount of spectrum capacity requires teasing out the impact due to the natural growth of IoT based on the extrapolation of current penetration rates. M2M adoption, as a metric of IoT deployment (the only available indicator to measure IoT), has reached an installed base of 24 million in 2020 (see Graphic 6-1).

Graphic 6-1. Brazil: Installed base of M2M devices (2010-2020)



Source: GSMA Intelligence

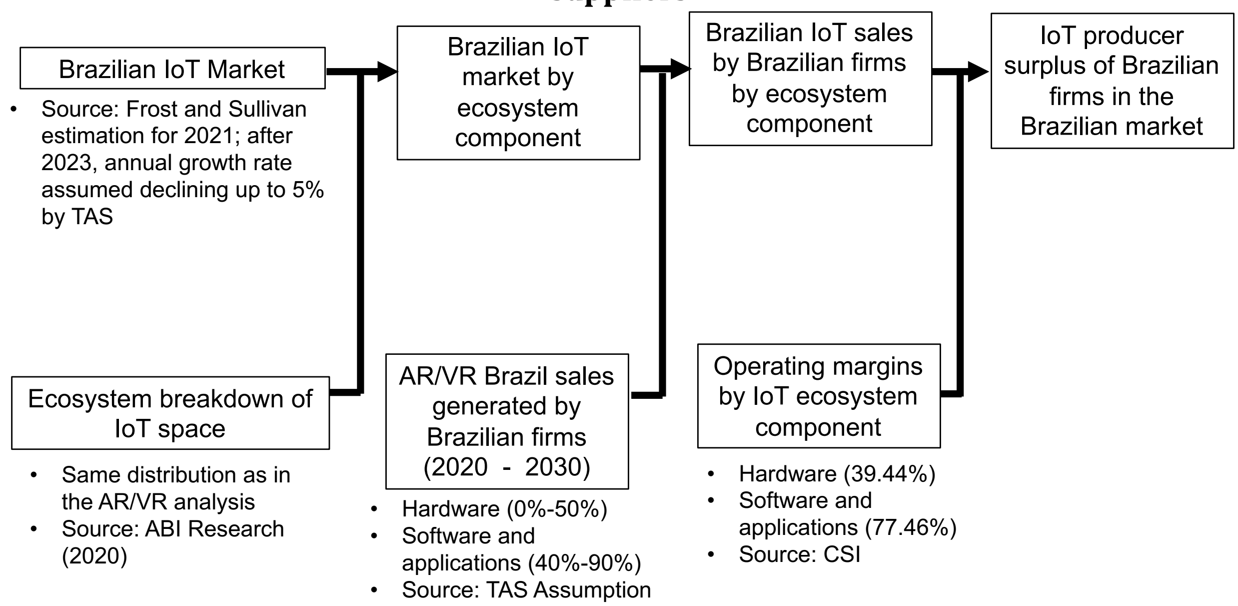
On the other hand, the IoT Brazilian market in 2020 is estimated at US$2.75 billion[62]. The enhanced deployment of IoT as a result of the 6 GHz allocation to unlicensed use will trigger two economic effects: (i) the generation of producer surplus (i.e. margins) of Brazilian eco-system suppliers in the IoT segment, and (ii) the spillover of IoT on the efficiency of Brazilian industries.

6.2. Producer surplus of IoT eco-system firms

The objective is to calculate the impact that the allocation of the 6 GHz band would have in terms of expanding the IoT installed base, thereby generating consumer surplus (i.e. operating margins) for the Brazilian suppliers of hardware, software, and systems integration (see figure 6-1)

[62] Frost & Sullivan (2021). *Industrial Internet of Things (IoT) revenue in Brazil (2016-2021).*

Figure 6-1. Methodology for estimating producer surplus from IoT Brazilian suppliers



Source: Telecom Advisory Services

Starting with a 2020 Brazilian IoT market revenues, we first estimate the portion that can be exclusively attributed to the additional spectrum allocation in 6 GHz. This estimate is calculated based on measuring the difference between the market growth of 19.50% reaching 5% in 2030, and an extrapolation of the past growth trend of M2M connections (see Table 6-1).

Table 6-1. Brazil: IoT market (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Industrial IoT revenue in Brazil	$ 2.75	$ 3.29	$ 3.93	$ 4.70	$ 5.45	$ 6.17	$ 6.85	$ 7.46	$ 8.01	$ 8.50	$ 8.92
(2) Growth rate of (1)	19.50%	19.50%	19.50%	19.50%	16.06%	13.22%	10.88%	8.96%	7.38%	6.07%	5.00%
(3) Sales due to 6GHz Band (%)	0.00%	1.68%	6.27%	16.42%	28.13%	40.43%	44.84%	48.61%	51.89%	54.77%	40.43%
(4) Sales due to 6 GHz Band (in US$ billion)	$ 0.00	$ 0.06	$ 0.25	$ 0.77	$ 1.53	$ 2.77	$ 3.34	$ 3.89	$ 4.41	$ 4.89	$ 2.77

Source: Frost & Sullivan (2018); Telecom Advisory Services analysis

In order to calculate the producer surplus, we need to estimate the breakdown of supplier components (hardware, software, and systems integration) (see table 6-2).

Table 6-2. Brazil: IoT market by ecosystem supplies (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	23.24%	16.56%	16.08%	16.59%	17.41%	19.05%	21.82%	26.07%	31.46%	37.91%	45.39%
Software and Apps	76.76%	83.44%	83.92%	83.41%	82.59%	80.95%	78.18%	73.93%	68.54%	62.09%	54.61%

Source: Frost & Sullivan (2018); ABI Research (2020); Telecom Advisory Services analysis

In addition, the portion of the market to be served by Brazilian providers was also estimated (see table 6-3).

Table 6-3. Brazil: Share of IoT market served by Brazilian suppliers (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	0.00%	5.00%	10.00%	15.00%	20.00%	25.00%	30.00%	35.00%	40.00%	45.00%	50.00%
Software and Apps	40.00%	45.00%	50.00%	55.00%	60.00%	65.00%	70.00%	75.00%	80.00%	85.00%	90.00%

Source: Frost & Sullivan (2018); ABI Research (2020); Telecom Advisory Services analysis

Based on the operating margins by component, the producer surplus for Brazilian providers of IoT solutions was estimated (see table 6-4).

Table 6-4. Brazil: Producer surplus of Brazilian IoT suppliers (in US$ billion) (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$ 0.00	$ 0.00	$ 0.00	$ 0.01	$ 0.02	$ 0.04	$ 0.07	$ 0.12	$ 0.19	$ 0.30	$ 0.44
Software and Apps	$ 0.00	$ 0.02	$ 0.08	$ 0.27	$ 0.59	$ 0.89	$ 1.17	$ 1.44	$ 1.65	$ 1.80	$ 1.86
Total	$ 0.00	$ 0.02	$ 0.08	$ 0.28	$ 0.61	$ 0.93	$ 1.24	$ 1.56	$ 1.85	$ 2.10	$ 2.30

Source: Frost & Sullivan (2018); ABI Research (2020); Telecom Advisory Services analysis

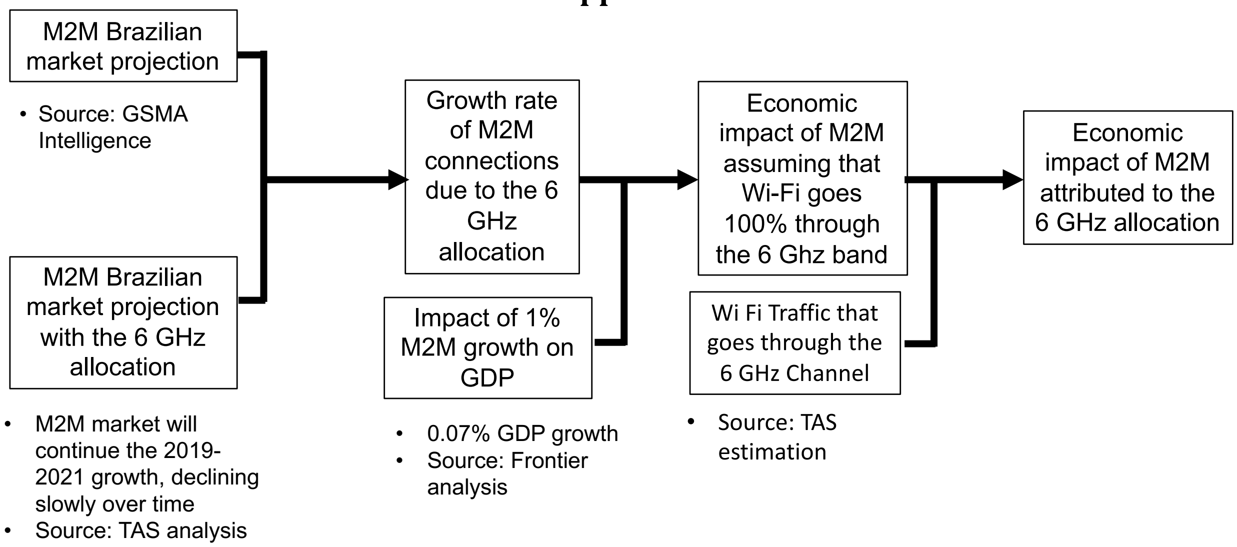
The total cumulative value of producer surplus driven by sales of IoT by Brazilian firms in Brazil amounts to US$10.96 billion.

6.3. Spillover of IoT deployment propelled by 6 GHz allocation in Brazil

IoT adoption contributes to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance and production monitoring. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function that estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9% (see figure 6-2).[63]

[63] *See* Frontier Economics (2018). *The economic impact of IoT: putting numbers on a revolutionary technology.*

Figure 6-2. Methodology for estimating producer surplus from IoT Brazilian suppliers



Source: Telecom Advisory Services

By relying on the middle coefficient of the GDP impact contribution (0.7% for each 10% of the installed base), we estimate that in 2021, the impact of IoT would be 0.01% of GDP. Considering that Brazilian GDP in 2021 will reach US$1,778 billion (source: IMF), it is estimated that the IoT impact for 2021 would reach $0.12 billion (see Table 6-5).

Table 6-5. Brazil: IoT Spillover (in US$ billion) (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Brazil with no 6 GHz	24,405,593	26,654,443	27,749,688	26,640,956	24,371,731	23,133,955	22,209,643	21,322,263	20,470,337	19,652,450	18,867,241
(2) Growth Rate (%)	11.08%	9.21%	4.11%	-4.00%	-4.00%	-4.00%	-4.00%	-4.00%	-4.00%	-4.00%	-4.00%
(3) Brazil with 6 GHz	24,405,593	27,108,691	29,606,617	31,876,266	33,909,260	35,708,485	37,284,780	38,654,072	39,835,096	40,847,673	41,711,503
(4) Growth Rate (%)	11.08%	11.08%	9.21%	7.67%	6.38%	5.31%	4.41%	3.67%	3.06%	2.54%	2.11%
(5) Growth due to 6.0 MHz (%)	0.00%	1.86%	5.11%	11.66%	10.37%	9.30%	8.41%	7.67%	7.05%	6.54%	6.11%
(6) Impact of 1% M2M Growth on GDP	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%
(7) Use of the 6 GHz Band	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(8) Impact on GDP (%)	0.00%	0.01%	0.05%	0.18%	0.22%	0.24%	0.26%	0.28%	0.30%	0.31%	0.32%
(9) Brazil GDP Billions US$	1,717	1,778	1,842	1,909	1,977	2,049	2,122	2,199	2,278	2,360	2,445
(10) Total Impact (US$ Billion)	0.00	0.17	0.99	3.51	4.31	5.00	5.62	6.20	6.75	7.29	7.84
(11) Direct Impact (US$ Billion)	0.00	0.06	0.25	0.77	1.53	2.17	2.77	3.34	3.89	4.41	4.89
(12) Indirect Impact (US$ Billion)	0.00	0.12	0.74	2.73	2.77	2.83	2.85	2.85	2.85	2.88	2.96

Source: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

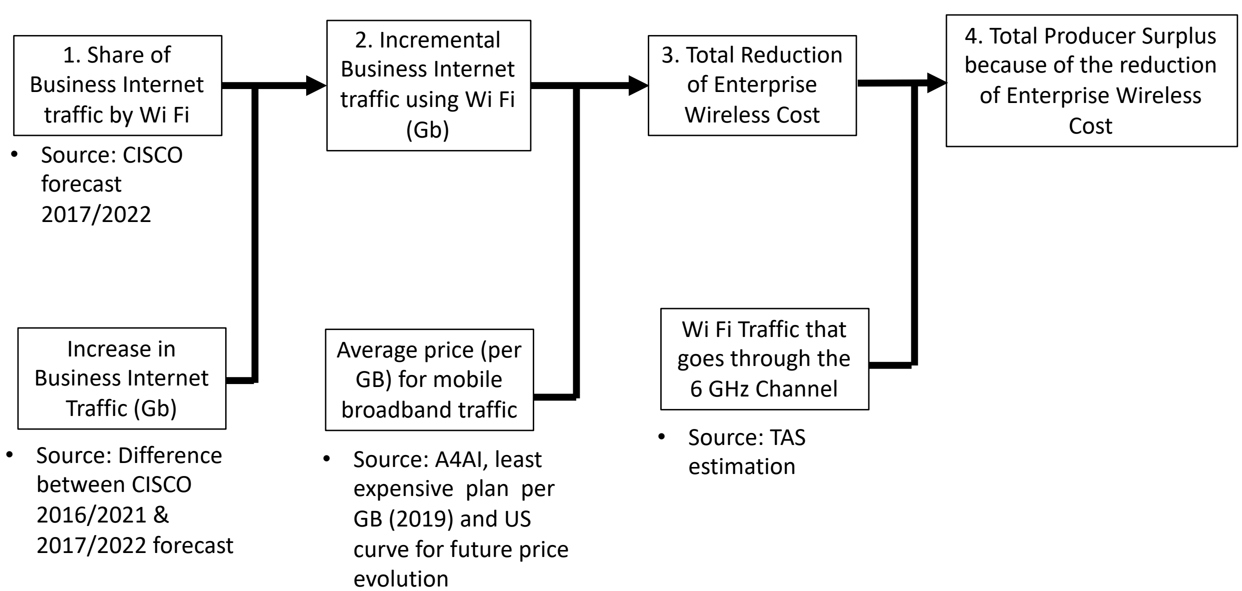
According to the data in line 12, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach US$23.59 billion by 2030.

7. REDUCTION OF ENTERPRISE WIRELESS COSTS

The deployment of the enterprise applications based on IoT and AR/VR (which is analyzed below) among other use cases will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing 2.4 GHz, the lower 5 GHz, and the 6 GHz band. Under current conditions, enterprise Wi-Fi networks run 20 or 40 MHz channels due to spectrum shortfall and device restrictions. Wi-Fi requires 80 MHz channels to offer 1 Gb of throughput, which provides an indication of existing constraints. Thus, 6 GHz allocation is critical to handle enterprise applications. The impact on GDP of having a suitable spectrum environment to run these applications has been addressed in the IoT and AR/VR chapters under the heading of spillovers.

The allocation of 6 GHz also has an economic effect in enterprise margins (or producer surplus), in terms of the savings from cellular usage implied by using unlicensed spectrum to handle traffic from high-capacity Wi-Fi devices rather than cellular networks. The methodology to assess this benefit proceeds by multiplying the average price per Gigabyte of wireless data transmitted by wideband networks, which we calculate by averaging the most economic "dollar per GB" (for the least expensive plans for 4G speeds) plan of major wireless carriers in Brazil (see figure 7-1).

Figure 7-1. Methodology for estimating a reduction in enterprise wireless cost



Source: Telecom Advisory Services

In 2018, the Cisco VNI estimated that for 2023 total business Internet traffic would reach 12.60 billion GB, of which 46.54% would be transported through Wi-Fi access points. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total Internet traffic reaching 13.10 billion GB, with the same percentage being routed through Wi-Fi[64] (see Table 7-1).

Table 7-1. Brazil: Enterprise Wireless Traffic ('000) (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Share of Business Internet Traffic by Wi Fi	51.05%	49.50%	48.00%	46.54%	45.13%	43.76%	42.43%	41.14%	39.89%	38.68%	37.51%
(2) Total Business Internet Traffic (Gb) (2016-21)	9,181,733	10,204,842	11,341,956	12,605,777	14,010,424	15,571,589	17,306,713	19,235,180	21,378,534	23,760,719	26,408,348
(3) Total Business Internet Traffic (Gb) (2017-22)	8,849,265	10,085,016	11,493,332	13,098,312	14,927,419	17,011,950	19,387,574	22,094,941	25,180,376	28,696,676	32,704,007
(4) Incremental Business Internet Traffic	0	0	151,376	492,535	916,995	1,440,361	2,080,861	2,859,767	3,801,843	4,935,957	6,295,659

Source: Cisco Visual Networking Index (2017), (2019)

Each growth forecast was converted to dollar values based on the price per GB[65] (see Table 7-2).

Table 7-2. Brazil: Cost of Enterprise Internet Traffic (2020-2030) (IN US$)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(5) Average Price per Gb	$1.47	$1.33	$1.19	$1.07	$0.96	$0.87	$0.78	$0.70	$0.63	$0.57	$0.51
(6) Economic Impact (US$ Billion)	$ 0.000	$ 0.000	$ 0.180	$ 0.528	$ 0.884	$ 1.249	$ 1.623	$ 2.007	$ 2.399	$ 2.802	$ 3.215

Source: A4AI; Telecom Advisory Services analysis

We assume that part of the traffic growth presented in table 7-2 will be driven driven by "natural" growth (that is to say, the extrapolation of historical growth rate of enterprise wireless traffic by averaging the growth rate between 2018 and 2019 and between 2016 and 2019), while the remainder will be triggered by Wi-Fi traffic stimulated by changes in 6 GHz (see Table 7-3).

Table 7-3. Brazil: Enterprise Wireless Traffic: Growth triggered by broader Wi-Fi traffic (2020-2030) (in '000'000 US$)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(7) Traffic through 6 GHz Band	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(8) Economic impact of 6 GHz Band (US$ Billion)	$ 0.000	$ 0.000	$ 0.027	$ 0.119	$ 0.265	$ 0.468	$ 0.730	$ 1.053	$ 1.440	$ 1.891	$ 2.411

Source: Telecom Advisory Services analysis

[64] Cisco's new forecast includes in its assumption set the deployment of Wi-Fi 6.
[65] According to the Alliance for Affordable Internet, in 2019 the price for a 2 GB plan was US$9.83, for a 5 GB plan was US$13.47, and for a 10 GB plan was US$16.38. When converted to price per GB for the highest capacity plan, it resulted in US$ 1.64. The coefficient of decline per annum was 0.8994.

The sum of the difference due to broader Wi-Fi traffic between 2020 and 2030 will reach US$8.405 billion.

8. DEPLOYMENT OF AR/VR SOLUTIONS

The AR/VR solutions market is developing at a fast pace driven by a broad range of applications (see table 8-1).

Table 8-1. Examples of AR/VR applications

Sector	Domain	Use Case	Example
Health Care	Diagnostic	Augmented reality has the potential to help patients before they are diagnosed with Alzheimer or Dementia	Altoida, is a company that develops virtual and augmented reality tools to predict the onset of mental illness in older patients, specifically neurodegenerative diseases[66]
	Surgical procedures	Platforms that combine visualization and display technologies with a new class of operating robots to support remote surgical interventions	Medivis, a company specialized in augmented reality suites in the health care domain, offers an augmented reality holographic visualization tool that guides surgical navigation, which can decrease complications and improve patient outcomes, while lowering surgical costs[67].
	Training in ER procedures	Since pediatric emergencies are rare, doctors have little training experience for helping children in emergencies, and traditional mannequin-based simulations are expensive.	VR is helping doctors at Children's Hospital Los Angeles be better prepared for real life scenarios by helping doctors learn their knowledge gaps. The program has also been expanded to 11 other sites, including Johns Hopkins and Stanford University health systems[68].
Retailing	Guest engagement	Provide customers with mall-wide Wi-Fi coverage, combined with guest engagement content as part of marketing campaigns[69].	Retailers are experimenting with the roll-out of enhanced Wi-Fi based portal and analytics platforms deployed in brick and mortar facilities.
Oil and Gas	Maintenance	Oil firms have adopted AR headsets and glasses, which superimpose digital images on what the wearer sees in real life to fix problems on rigs, refineries and plants. The technology transmits information in real-time to experts located anywhere in the world, who can then respond with instructions and guidance to a technician on-site.	Fieldbit, among many firms, is creating[70] technology that aims to prevent technician issues and oil spills in the oil and gas industry. This emerging technology is already being used by Chevron, BP, and Baker Hughes
Mining	Emergency rescue operations training	Virtual reality creates situations that are impossible to recreate in the physical world in order to train rescue personnel	Volunteer rescuers navigate emergency underground simulations to train rescue volunteers to hone their emergency-response skills in a safe but realistic environment[71]

Source: Compilation by Telecom Advisory Services

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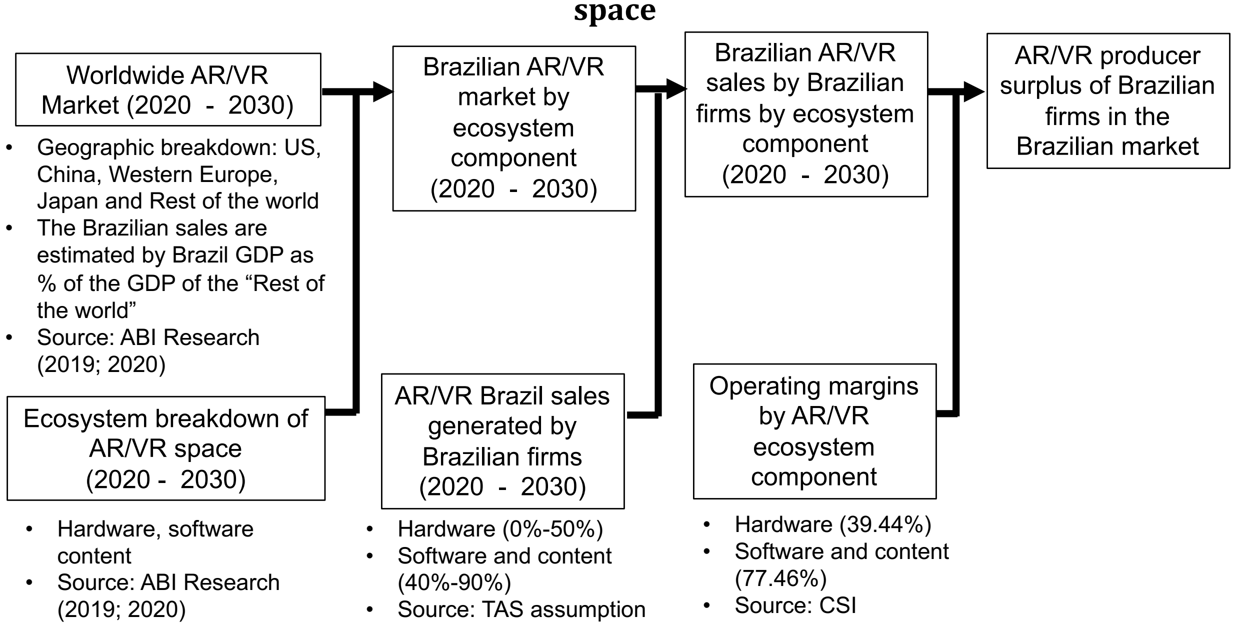
[66] Shieber, J. "Using augmented reality, Altoida is identifying the likely onset of neurodegenerative diseases", *Techcrunch*, May 30, 2019.
[67] Shrieber, J. "Robotics, AR and VR are poised to reshape health-care, starting in the operating room". *Techcrunch*, February 21, 2019.
[68] Preparing for emergencies before they happen
[69] See example of American Dream Megamall, one of the largest US malls located in New Jersey.
[70] Margit, M. (2019). *How Augmented Reality is Transforming the Oil Industry*
[71] Mine rescue teams discover a new tool for training

The AR/VR market in Brazil is estimated at US$195 million, of which US$45 million is hardware (such as smart and non-smart glasses), and US$150 million is software and applications (including systems integration, platform and licensing). By 2024 the market will reach US$1.968 billion (US$343 million hardware and US$1.625 billon software and applications)[72]. Sales by Brazilian firms to Brazilian businesses will generate producer surplus (i.e. margins), while the technology will yield spillovers in enterprise productivity.

8.1. Producer surplus derived from sale of Virtual Reality and Augmented Reality solutions

The development and diffusion of AR/VR applications in the production side of the economy is being driven by an ecosystem comprised of firms ranging from software development to hardware production and content creation. The key objective is to estimate the producer surplus generated in Brazil as a result of the sales of AR/VR applications produced by domestic firms (see Figure 8-1).

Figure 8-1. Methodology for estimating Brazilian producer surplus in the AR/VR space



Source: Telecom Advisory Services

Our starting point is the sales of AR/VR applications and systems within Brazil between 2020 and 2030 (one could potentially include exports to other countries, although we exclude this for conservative purposes). We estimate this by prorating Latin American projections for Brazil based on its GDP and break it down by ecosystem component according to ABI Research (2019, 2020) studies (see table 8-2).

[72] Data calculated based on Latin American totals as estimated by ABI Research (2019, 2020).

Table 8-2. Brazil: AR/VR market by component (2020-2030) (in US$ billions)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$ 0.05	$ 0.07	$ 0.13	$ 0.21	$ 0.34	$ 0.55	$ 0.88	$ 1.41	$ 2.23	$ 3.47	$ 5.37
Software & Applications	$ 0.15	$ 0.37	$ 0.66	$ 1.06	$ 1.63	$ 2.34	$ 3.17	$ 4.00	$ 4.85	$ 5.68	$ 6.46
TOTAL	$ 0.20	$ 0.45	$ 0.78	$ 1.28	$ 1.97	$ 2.89	$ 4.05	$ 5.41	$ 7.07	$ 9.15	$ 11.83

Source: ABI Research (2019); Telecom Advisory Services analysis

Sales are broken down by two components of the ecosystem: hardware and applications and software, but each component is restricted to the Brazilian firms, because the purpose is to estimate the value generated by the domestic producers (therefore, we exclude sales in Brazil generated by foreign firms). A key assumption in this regard is that Brazilian firms do not currently sell hardware in AR/VR space, although that share will increase over time reaching 50% by 2030. On the other hand, Brazilian firms are assumed to hold 40% for software and content market, reaching 90% in 2030. This recognizes that the development of this market should be accompanied by a concerted industrial policy aimed at developing local firms in these two components (see Table 8-3).

Table 8-3. Brazil: AR/VR sales by Brazilian firms by component (2020-2030) (in US$ billions)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$ 0.00	$ 0.00	$ 0.01	$ 0.03	$ 0.07	$ 0.14	$ 0.26	$ 0.49	$ 0.89	$ 1.56	$ 2.69
Software & Applications	$ 0.06	$ 0.17	$ 0.33	$ 0.59	$ 0.98	$ 1.52	$ 2.22	$ 3.00	$ 3.88	$ 4.83	$ 5.82
TOTAL	$ 0.06	$ 0.17	$ 0.34	$ 0.62	$ 1.04	$ 1.66	$ 2.48	$ 3.49	$ 4.77	$ 6.39	$ 8.50

Source: ABI Research (2019; 2020); Telecom Advisory Services analysis

Once sales by Brazilian firms in the Brazilian market are calculated, producer surplus for the AR/VR Brazilian industry is estimated based on standard margin metrics: 39.44% for hardware, and 77.46% for software and content (see Table 8-4).

Table 8-4. Brazil: Producer surplus derived from AR/VR sales by Brazilian firms by component (2020-2030) (in US$ billions)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$ 0.00	$ 0.00	$ 0.01	$ 0.02	$ 0.03	$ 0.05	$ 0.10	$ 0.19	$ 0.35	$ 0.62	$ 1.06
Software & Applications	$ 0.05	$ 0.13	$ 0.25	$ 0.45	$ 0.75	$ 1.18	$ 1.72	$ 2.32	$ 3.00	$ 3.74	$ 4.50
TOTAL	$ 0.05	$ 0.13	$ 0.26	$ 0.47	$ 0.78	$ 1.23	$ 1.82	$ 2.52	$ 3.36	$ 4.36	$ 5.56

Source: CSI Market Inc *: Industry Profitability ratios; ABI Research (2019, 2020); Telecom Advisory Services analysis*

It is clear that a portion of this surplus is not due exclusively to the designation of Very Low Power devices within the 6 GHz band. The development of AR/VR has already begun before this potential spectrum change. Therefore, the producer surplus estimated in table 8-4 must be broken down between the portion that is due to the "natural" growth in the industry and the boost resulting from the spectrum designation mentioned above. In the absence of any precise metric, we applied the ratio used to determine the impact on AR/VR market growth ranging between 6.70% of sales in 2021 and 65.53% in 2030. Based on this analysis, the producer surplus to be generated by Brazilian AR/VR firms from sales in the Brazilian market between 2020 and 2030 due to the 6 GHz allocation will amount to US $10.23 billion (see Table 8-5).

Table 8-5. Brazil: AR/VR sales by US firms by component attributed to the designation of Very Low Power devices within the 6GHz band (2020-2030) (in US$ billions)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Due to 6 Ghz (%)	0.00%	6.70%	11.49%	15.47%	21.60%	28.34%	34.95%	42.15%	50.48%	58.73%	65.53%
Due to 6 GHz (US$ B)	$ 0.00	$ 0.01	$ 0.03	$ 0.07	$ 0.17	$ 0.35	$ 0.64	$ 1.06	$ 1.69	$ 2.56	$ 3.65

Source CSI Market Inc *: Industry Profitability ratios; ABI Research; Telecom Advisory Services analysis .*

8.2. Spillovers from Virtual Reality and Augmented Reality

The adoption of AR/VR among Brazilian businesses will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. The spillover effects range from improved training to the acceleration of product design and delivery. For example, automotive companies are already incorporating VR in their product development processes to reduce the time incurred between initial design and physical modelling. AR glasses also help warehouse workers provide parts information for engineers and technicians in the field. Finally, as shown in the applications table above, AR/VR solutions can be used to sell and showcase products in retailing.

Because the objective is to estimate the spillover effect of AR/VR sales by Brazilian firms in the domestic market resulting from the growth driven by designating VLP devices as part of the 6 GHz band, our point of departure is the total GDP contribution of AR/VR, as estimated by PwC that indicates the weight of AR/VR in the GDP by region[73], and the sales of AR/VR components as derived from ABI Research data (see table 8-1). These two parameters allow estimating the indirect (that is to say spillover) contribution of AR/VR to the Brazilian economy (see Figure 8-2).

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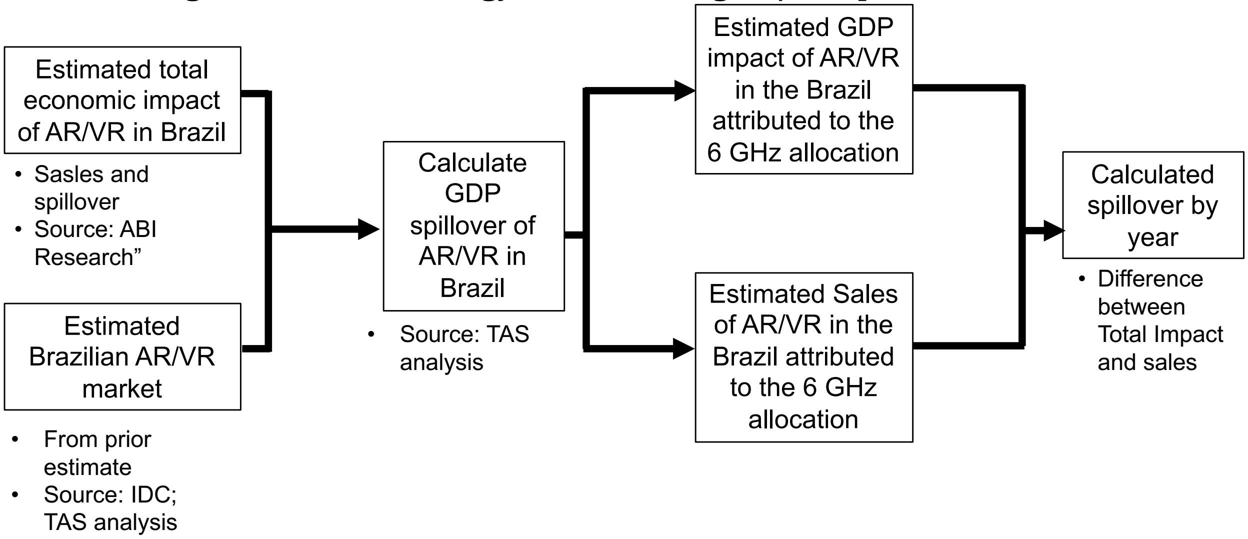
[73] PWC (2019). *Seeing is believing: how virtual reality and augmented reality are transforming business and the economy.*

Figure 8-2. Methodology for estimating AR/VR spillovers



Source: Telecom Advisory Services

Both starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum allocation of VLP devices (in other words, it would be wrong to estimate that the whole economic value of the AR/VR is driven by the spectrum changes). Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated (see Table 8-6).

Table 8-6. Brazil: GDP Contribution resulting from AR/VR Spillovers (2020-2030) (in US$ billion)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
AR/VR Boost to GDP (% GDP)	0.10%	0.15%	0.20%	0.25%	0.31%	0.38%	0.46%	0.56%	0.70%	0.89%	1.12%
Brazil GDP (Millions)	1,716.5	1,778.3	1,842.3	1,908.7	1,977.4	2,048.6	2,122.3	2,198.7	2,277.9	2,359.9	2,444.8
AR/VR Boost to GDP (US$ Millions)	1,717	2,667	3,685	4,772	6,130	7,785	9,763	12,313	15,945	21,003	27,382
AR/VR Boost to GDP without 6.0 GHz Band (US$ Millions)	1,717	2,489	3,261	4,034	4,806	5,578	6,351	7,123	7,895	8,668	9,440
AR/VR Boost to GDP due to 6.0 GHz Band (US$ Millions)	0	179	423	738	1,324	2,206	3,412	5,190	8,050	12,335	17,942
Direct impact	0.000	0.030	0.090	0.197	0.425	0.820	1.415	2.279	3.571	5.374	7.753
Indirect impact	0.000	0.149	0.334	0.541	0.899	1.386	1.997	2.910	4.478	6.961	10.189

Source: ABI Research (2019); CSI Market Inc *: Industry Profitability ratios; Telecom Advisory Services analysis.*

Total spillover value of AR/VR in Brazil (the indirect impact) between 2021 and 2030 is US$29.84 billion. When considering the size of the AR/VR market in Brazil, relative to the indirect spillover, that yields an average multiplier between 2020 and 2030 of 2.69.

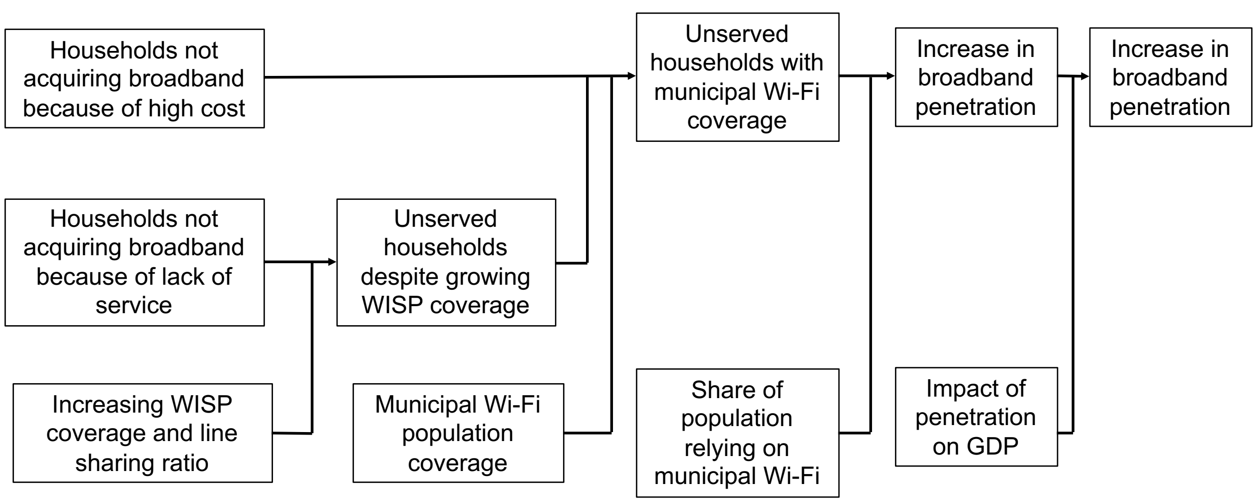
9. ENHANCED DEPLOYMENT OF MUNICIPAL WI-FI

It is estimated that 2,134 (or 38.33 %) Brazilian municipalities already offer free Wi-Fi service[74]. This infrastructure can play a role in enhancing broadband service coverage by providing a free resource for consumers to gain access to the Internet. Along these lines, allocating spectrum in the 6 GHz band will increase the ability of municipal Wi-Fi to provide free service to unserved population or increase the speed of access for current users. These two effects translate into a contribution to GDP and an increase in consumer surplus.

9.1. Impact of enhanced Municipal Wi-Fi on GDP

The municipal Wi-Fi sites that incorporate technology relying on 6 GHz spectrum will be able to handle a larger number of users than under the current spectrum conditions which that will in turn have an impact on the GDP. The methodology to estimate this effect is presented in figure 9-1.

Figure 9-1. Methodology for estimating GDP impact of Municipal Wi-Fi



Source: Telecom Advisory Services

The universe for assessing the impact of municipal Wi-Fi is the urban environment, where 80% of the Brazilian population resides. According to the Cetic.br survey of 2019, 6.54% of urban households (or 4,017,410) do not acquire broadband service for economic reasons ("Porque os moradores acham muito caro"), while 0.64% (or 392,645) do not do so for lack of service coverage ("Por falta de disponibilidade de Internet na região do domicilio"). In order to determine the universe benefitting from municipal broadband, we discounted from the households lacking coverage, the increased deployment of WISPs. By 2021, the first year of impact of this last variable, the number of benefitting households reaches 32,348. As a result, the number of "digital divide" households is 4,377,707, declining to 3,899,206 by 2030 (see table 9-1).

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[74] TAS Analysis using IBGE, *Pesquisa de Informações Básicas Municipais* - 2014 data

Table 9-1. Brazil: "Digital Divide" households ('000)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Households that don´t buy because of limited affordability in urban areas	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017
(2) Households that don´t buy because lack of coverage at their homes in urban areas	393	393	393	393	393	393	393	393	393	393	393
(3) Households that now are served by WISP	0	32	73	120	172	227	284	342	399	456	511
(4) Digital divide households	4,410	4,378	4,337	4,290	4,238	4,183	4,126	4,068	4,011	3,954	3,899

Source: CeTic.Br; ANATEL; Telecom Advisory Services analysis.

Given that, by 2020, 38.33% of all Brazilian municipalities have deployed municipal Wi-Fi networks[75], the number of households that could potentially rely on this service for Internet access is smaller. However, the number of municipalities that have deployed municipal Wi-Fi is expected to increase over time, reaching 75% by 2030. Beyond this trend, we need to isolate the number of households that would benefit from municipal Wi-Fi networks being able to rely on 6 GHz spectrum. This resource would allow municipal networks to serve a larger number of users than under current unlicensed spectrum allocation. Furthermore, it is expected that not all unserved households would rely on municipal Wi-Fi due to geographic reasons, time availability and the like. Along these lines, we assume that, conservatively, only 10% of unserved households would use the municipal service (see table 9-2).

Table 9-2. Brazil: Households benefitting from Municipal Wi-Fi Networks with 6 GHz spectrum

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(4) Digital divide households	4,410	4,378	4,337	4,290	4,238	4,183	4,126	4,068	4,011	3,954	3,899
(5) Municipal Wi-Fi deployment (% Total Municipalities)	38.33%	40.99%	43.83%	46.88%	50.13%	53.61%	57.34%	61.32%	65.58%	70.13%	75.00%
(6) Share of the population that have access to a Wi-Fi Municipal point	43.20%	43.84%	44.48%	45.14%	45.80%	46.48%	47.16%	47.86%	48.56%	49.27%	50.00%
(7) Traffic through 6 GHz Band	0%	8%	15%	23%	30%	38%	45%	53%	60%	68%	75%
(8) New households that now can have broadband	0	58,996	126,850	204,237	291,943	390,876	502,086	626,783	766,349	922,370	1,096,652
(9) Share of population that effectively goes to a Municipal Wi-Fi Point	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
(10) Number of households relying on municipal Wi-Fi	0	5,900	12,685	20,424	29,194	39,088	50,209	62,678	76,635	92,237	109,665

Source: IBGE; Telecom Advisory Services analysis.

[75] Extrapolation of IBGE, *Pesquisa de Informações Básicas Municipais* - 2014 data

The number of households that will be able to benefit from municipal Wi-Fi networks gaining access to 6 GHz spectrum represents an increase in the total of Brazilian served households. The increase in broadband penetration multiplied by the coefficient of impact of fixed broadband on GDP[76] yields the total GDP impact (see table 9-3).

Table 9-3. Brazil: GDP impact of Municipal Wi-Fi networks with 6 GHz spectrum

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(10) Number of households relying on municipal Wi-Fi	0	5,900	12,685	20,424	29,194	39,088	50,209	62,678	76,635	92,237	109,665
(11) Households with Fixed Broadband (000'000)	34.072	35.431	37.023	38.884	41.042	44.042	44.483	44.928	45.377	45.831	46.289
(12) Increase in national broadband penetration	0.00%	0.02%	0.03%	0.05%	0.07%	0.09%	0.11%	0.14%	0.17%	0.20%	0.24%
(13) Impact of fixed broadband adoption in GDP	0.1574	0.1574	0.1574	0.1574	0.1574	0.1574	0.1574	0.1574	0.1574	0.1574	0.1574
(14) Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%	0.03%	0.03%	0.04%
(15) GDP (US$ Billion)	$ 1,893	$ 1,988	$ 2,084	$ 2,189	$ 2,296	$ 2,408	$ 2,526	$ 2,650	$ 2,780	$ 2,916	$ 3,058
(16) Total impact in GDP (US$ Billion)	$ 0.000	$ 0.052	$ 0.112	$ 0.181	$ 0.257	$ 0.337	$ 0.449	$ 0.582	$ 0.739	$ 0.924	$ 1.141

Source: IMF; ITU; Telecom Advisory Services analysis.

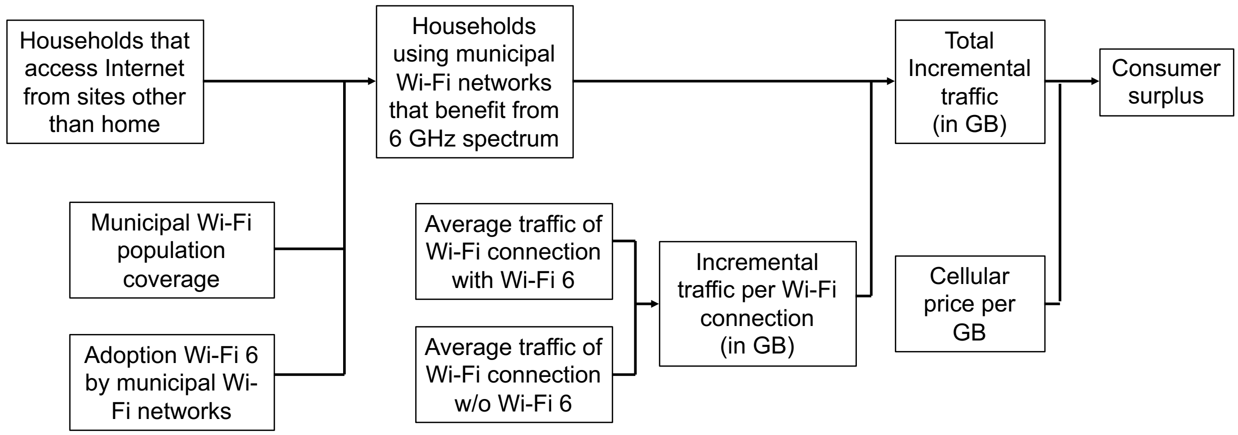
In sum, the cumulative contribution of GDP of the benefit accorded to municipal Wi-Fi networks by allocating spectrum in the 6 GHz band will reach US$4.77 billion.

9.2. Contribution of enhanced Municipal Wi-Fi on consumer surplus

In addition to the contribution to GDP, municipal Wi-Fi networks with the capacity to leverage spectrum in 6 GHz can enhance their performance, providing faster broadband service, and thereby generating incremental consumer surplus (see Figure 9-2).

[76] Katz, R. and Callorda, F. (2019). *Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the Americas*. Geneva: International Telecommunications Union.

Figure 9-2. Methodology for estimating consumer surplus of Municipal Wi-Fi



Source: Telecom Advisory Services analysis

The basis of this analysis is to estimate the difference in the download speed of municipal Wi-Fi service before and after the allocation of 6 GHz spectrum for those households that do not purchase broadband service and are compelled to rely on this service to gain Internet access. We start by relying on Cetic.br survey data indicating those households that access the Internet from sites away from home (e.g. work, place of study, free sites, and municipal Wi-Fi): 1,077,742. Of this universe, not all households have the capability of relying on municipal Wi-Fi because not all municipalities have deployed networks (as mentioned above, only 38.33% have done so, which based on their geographic coverage, amounts to 43.20% of the population served by those municipalities). Because the objective is to estimate the incremental impact of 6 GHz, we factor the population coverage by Wi-Fi 6 adoption in municipal Wi-Fi networks, which is assumed to grow from 8% in 2021 to 75% in 2030. This yields the population that accesses the Internet away from home who benefit from municipal Wi-Fi that has adopted Wi-Fi 6: it starts at 14,524 in 2021 and increases to 303,115 in 2030 (see table 9-4).

Table 9-4. Brazil: Households benefiting from municipal Wi-Fi that have adopted Wi-Fi 6

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Households that do not buy broadband service because have access in another place in urban areas ('000)	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078
(2) Municipal Wi Fi deployment (% Total Municipalities)	38.33%	40.99%	43.83%	46.88%	50.13%	53.61%	57.34%	61.32%	65.58%	70.13%	75.00%
(3) Share of the population that have access to a Wi Fi Municipal point	43.20%	43.84%	44.48%	45.14%	45.80%	46.48%	47.16%	47.86%	48.56%	49.27%	50.00%
(4) Municipal networks adopting Wi-Fi 6	0%	8%	15%	23%	30%	38%	45%	53%	60%	68%	75%
(5) Households covered by Wi-Fi Municipal with 6 GHz band	0	14,524	31,523	51,312	74,243	100,709	131,145	166,035	205,918	251,390	303,115

Source: Cetic.Br; IBGE; Telecom Advisory Services analysis.

These households will benefit from the incremental traffic generated under Wi-Fi 6. To estimate this, we assume that current traffic per line stays at current level, while under Wi-Fi 6 it will grow as projected by CISCO VNI. The difference is multiplied by the price per GB in Brazil as reported by the Alliance for Affordable Internet for Brazil (see table 9-5).

Table 9-5. Brazil: Consumer surplus of households benefitting from municipal Wi-Fi in networks that have adopted Wi-Fi 6

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(6) Traffic after speed increase (Gb)	20.08	23.32	27.10	31.49	36.58	42.50	49.38	57.38	66.66	77.45	89.99
(7) Traffic with speed without 6 GHz (Gb)	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08
(8) Yearly Increase in traffic (Billions of Gb)	0.000	0.001	0.002	0.007	0.014	0.025	0.043	0.069	0.107	0.161	0.237
(9) Price per Gb	$ 1.47	$ 1.33	$ 1.19	$ 1.07	$ 0.96	$ 0.87	$ 0.78	$ 0.70	$ 0.63	$ 0.57	$ 0.51
(10) Total impact in consumer surplus (US$ Billion)	$ 0.000	$ 0.001	$ 0.003	$ 0.007	$ 0.013	$ 0.022	$ 0.034	$ 0.049	$ 0.068	$ 0.092	$ 0.121

Source: CISCO VNI 2017-2022; Alliance for Affordable Internet; Telecom Advisory Services analysis.

The cumulative consumer surplus to be generated by this effect amounts to US$408 million.

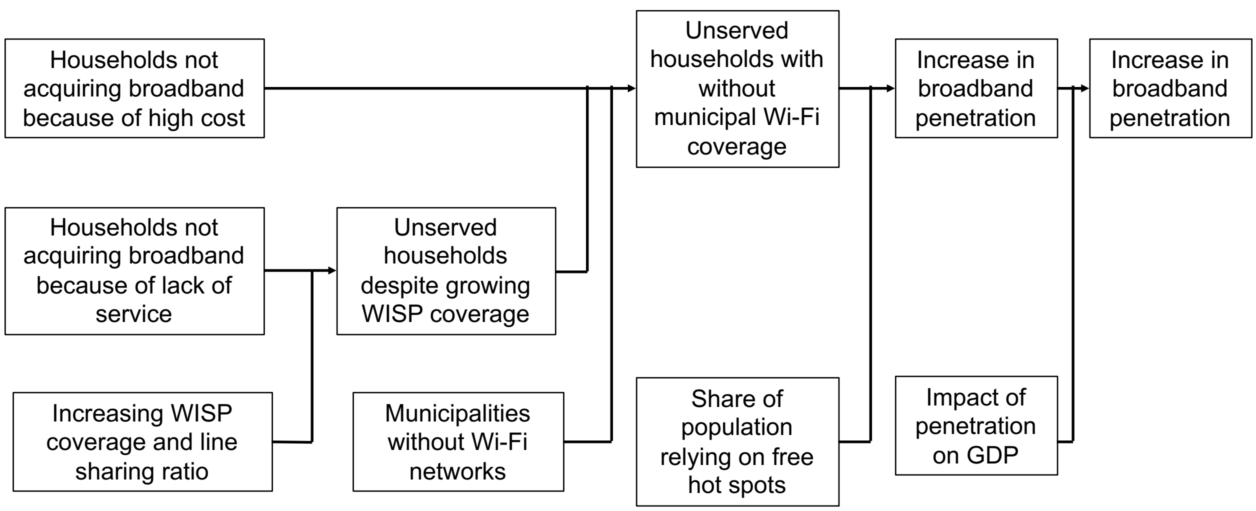
10. DEPLOYMENT OF FREE WI-FI HOT SPOTS

The assessment of economic impact of the 6 GHz allocation in the case of free hot spots is fairly similar to the one conducted for municipal Wi-Fi networks. The underlying assumption in this case is that free Wi-Fi hot spots that benefit from 6 GHz spectrum will be capable of handling a higher number of devices, which in turn will contribute to broadband adoption. On the other hand, these sites will be able to deliver faster speed of service, which can be transferred to increasing consumer well-being.

10.1. Impact of enhanced free Wi-Fi hot spots on GDP

As in the case of municipal Wi-Fi networks, the free hot spot sites that incorporate technology relying on 6 GHz spectrum will be able to handle a larger number of users than under the current spectrum conditions which would in turn have an impact on the GDP. The methodology to quantify this effect is presented in figure 10-1.

Figure 10-1. Methodology for estimating GDP impact of Municipal Wi-Fi



Source: Telecom Advisory Services

Our starting point is the households that lack broadband access at home due to limited affordability and that do not have the benefit of relying on municipal Wi-Fi. We subtract from this universe, those households that will be served by WISPs in the future, so as not to incur in double counting. From this group, we estimate those that could be served by free sites having implemented Wi-Fi 6 and assume that only 5% of them will effectively rely on a free site to gain Internet access. This is the incremental broadband penetration that is used to quantify the impact on GDP by relying on the same coefficient as the one used in the case of municipal Wi-Fi (see table 10-1).

Table 10-1. Brazil: GDP impact of Free Wi-Fi hot spots with 6 GHz spectrum

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Households that do not purchase broadband because affordability in urban areas ('000)	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017	4,017
(2) Households that do not purchase broadband because lack of coverage at their homes in urban areas ('000)	393	393	393	393	393	393	393	393	393	393	393
(3) Households that are served by WISPs	0	32,348	73,115	120,280	172,100	227,077	283,931	341,577	399,098	455,733	510,849
(4) Potential Free Wi-Fi coverage (households) ('000)	4,410	4,378	4,337	4,290	4,238	4,183	4,126	4,068	4,011	3,954	3,899
(5) Municipalities that do not have Wi-Fi networks	61.67%	59.01%	56.17%	53.12%	49.87%	46.39%	42.66%	38.68%	34.42%	29.87%	25.00%
(6) Share of the population that have access to Municipal Wi-Fi	43.20%	43.84%	44.48%	45.14%	45.80%	46.48%	47.16%	47.86%	48.56%	49.27%	50.00%
(7) Traffic through 6 GHz Band	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(8) New households that now can have broadband ('000)	0	84.94	162.53	231.44	290.39	338.17	373.58	395.39	402.28	392.85	365.55
(9) Share of population that effectively goes to a Free Wi Fi Spot	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
(10) Households with Fixed Broadband ('000)	34,073	35,431	37,023	38,884	41,042	44,042	44,483	44,928	45,377	45,831	46,289
(11) Increase in national broadband penetration	0.00%	0.01%	0.02%	0.03%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
(12) Impact of fixed broadband adoption in GDP	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745	0.15745
(13) Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
(14) GDP (US$ Billion)	1,893	1,988	2,084	2,189	2,296	2,408	2,526	2,650	2,780	2,916	3,058

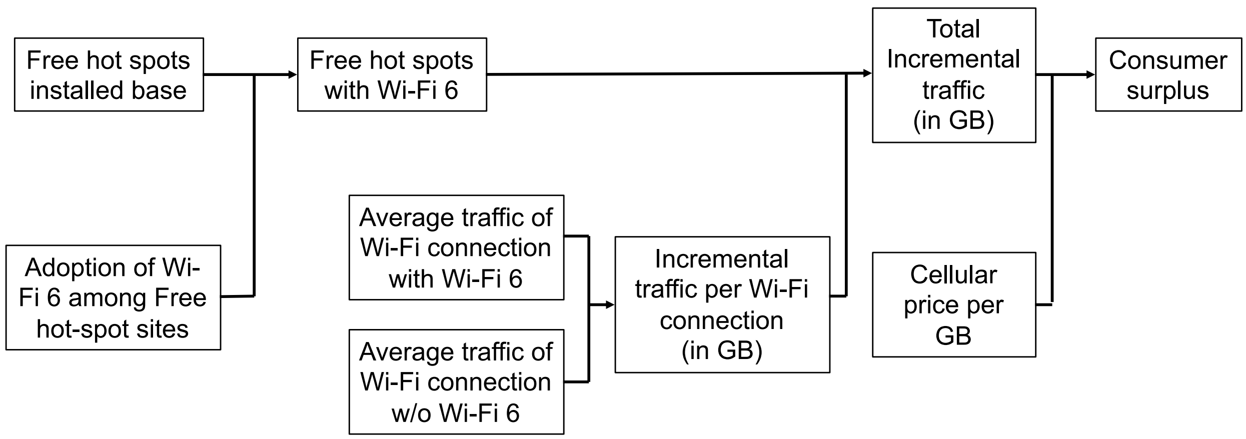
Source: Cetic.Br; IBGE; UIT; IMF; ITU; Telecom Advisory Services analysis.

The cumulative GDP contribution to be generated by this effect amounts to US$278 million.

10.2. Impact of enhanced free Wi-Fi hot spots on consumer surplus

The adoption of Wi-Fi 6 technology across free Wi-Fi hot spots will render them capable of delivering faster throughput (similar to the case of municipal Wi-Fi networks). By applying the price per GB for the incremental traffic to be conducted through the free sites, we estimate the consumer surplus (see table 10-2).

Table 10-2. Brazil: Consumer surplus of users benefitting from free Wi-Fi in networks that have adopted Wi-Fi 6



Source: Telecom Advisory Services

Assuming the same Wi-Fi 6 adoption among free hot spots, the incremental traffic generated under Wi-Fi 6 is quantified. To estimate this, we assume that current traffic per line stays at the current levels, while under Wi-Fi 6 it will grow as projected by CISCO VNI. The difference is multiplied by the price per GB in Brazil as reported by the Alliance for Affordable Internet (see table 10-2).

Table 10-2. Brazil: Consumer surplus of households benefitting from municipal Wi-Fi in networks that have adopted Wi-Fi 6

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Free hotspots ('000)	2,326	2,326	2,326	2,326	2,326	2,326	2,326	2,326	2,326	2,326	2,326
(2) Traffic through 6 GHz Band	0%	8%	15%	23%	30%	38%	45%	53%	60%	68%	75%
(3) Hotspots using the 6 GHz Band ('000)	0	174	349	523	698	872	1,047	1,221	1,396	1,570	1,744
(4) Traffic after speed increase (Gb)	20.08	23.32	27.10	31.49	36.58	42.50	49.38	57.38	66.66	77.45	89.99
(5) Traffic with speed without 6 GHz (Gb)	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08	20.08
(6) Yearly Increase in traffic (Billions of Gb)	0.000	0.006	0.027	0.067	0.129	0.219	0.343	0.509	0.727	1.007	1.363
(7) Price per Gb	1.47	1.33	1.19	1.07	0.96	0.87	0.78	0.70	0.63	0.57	0.51
(8) Total impact in consumer surplus (US$ Billion)	0.000	0.008	0.033	0.072	0.124	0.190	0.267	0.357	0.459	0.571	0.696

Source: Wiman; CISCO VNI 2017-2022; Alliance for Affordable Internet; Telecom Advisory Services analysis.

The cumulative consumer surplus to be generated by this effect amounts to US$2.777 million.

11. ALIGNING SPECTRUM DECISION WITH OTHER ADVANCED ECONOMIES

As stated in chapter 3, by allocating spectrum in the 6 GHz band, Brazil will not only alleviate the pressure on unlicensed spectrum resulting from explosive Wi-Fi usage, but will also have implications for the cost of inputs for Brazilian firms and for the country's industrial policy. If Brazil was to align itself with the United States and Korean 6 GHz allocation model, it would benefit from acquiring equipment whose average selling price would be lower than the equipment used in the European one. Our comparison of unit prices of AR monocular glasses indicates a persistent advantage of the US model relative to the European model (see table 11-1).

Table 11-1. United States versus Europe: Average Selling Price of Monocular glasses

	2019	2020	2021	2022	2023	2024
United States	761.16	709.14	656.94	606.29	564.49	528.85
Europe	766.25	715.60	665.82	617.24	574.03	537.53
Percent difference	-0.66%	-0.90%	-1.33%	-1.77%	-1.66%	-1.61%

Source: ABI Research 2020-2024; Telecom Advisory Services analysis

By extrapolating the trend through 2030 and applying the price difference to the AR/VR hardware and IoT hardware market, the following effect can be quantified (see table 11-2).

Table 11-2. Advantage of aligning the 6 GHz decision with the US model

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) AR-VR hardware market	0.045	0.074	0.126	0.212	0.343	0.551	0.883	1.410	2.225	3.469	5.370
(2) IoT Hardware Market	0.640	0.545	0.632	0.779	0.949	1.176	1.493	1.945	2.519	3.221	4.049
(3) Price reduction due to aligning spectrum decision	-0.90%	-1.33%	-1.77%	-1.66%	-1.61%	-1.54%	-1.47%	-1.40%	-1.34%	-1.28%	-1.22%
(4)Impact on producer surplus (US$B)	$ 0.006	$ 0.008	$ 0.013	$ 0.016	$ 0.021	$ 0.027	$ 0.035	$ 0.047	$ 0.063	$ 0.085	$ 0.115

Source: Telecom Advisory Services analysis

Secondly, as mentioned in chapter 3, the Brazilian market for equipment and services in areas related to implementation of the 6 GHz allocation amounts to US$ 3.13 billion in 2020 but will reach US$9.23 billion in 2025 (see table 11-3).

Table 11-3. Brazil: Sales in markets impacted by the 6 GHz decision (in US$ billion) (2020-25)

Market	Categories	2020	2025
Augmented Reality/Virtual Reality	Hardware	$ 0.05	$ 0.55
	Software and applications	$ 0.15	$ 2.34
	Subtotal	$ 0.20	$ 2.89
IoT	Hardware	$ 0.40	$ 1.17
	Software and services	$ 2.11	$ 4.99
	Subtotal	$ 2.75	$ 6.17
Wi-Fi devices	Home networking devices	$ 0.02	$ 0.02
	Wi-Fi enabled devices	$ 0.08	$ 0.07
	Enterprise access points and controllers	$ 0.08	$ 0.08
	Subtotal	$ 0.18	$ 0.17
Total		$ 3.13	$ 9.23

Source: ABI Research (2020); Frost & Sullivan (2019); Telecom Advisory Services analysis

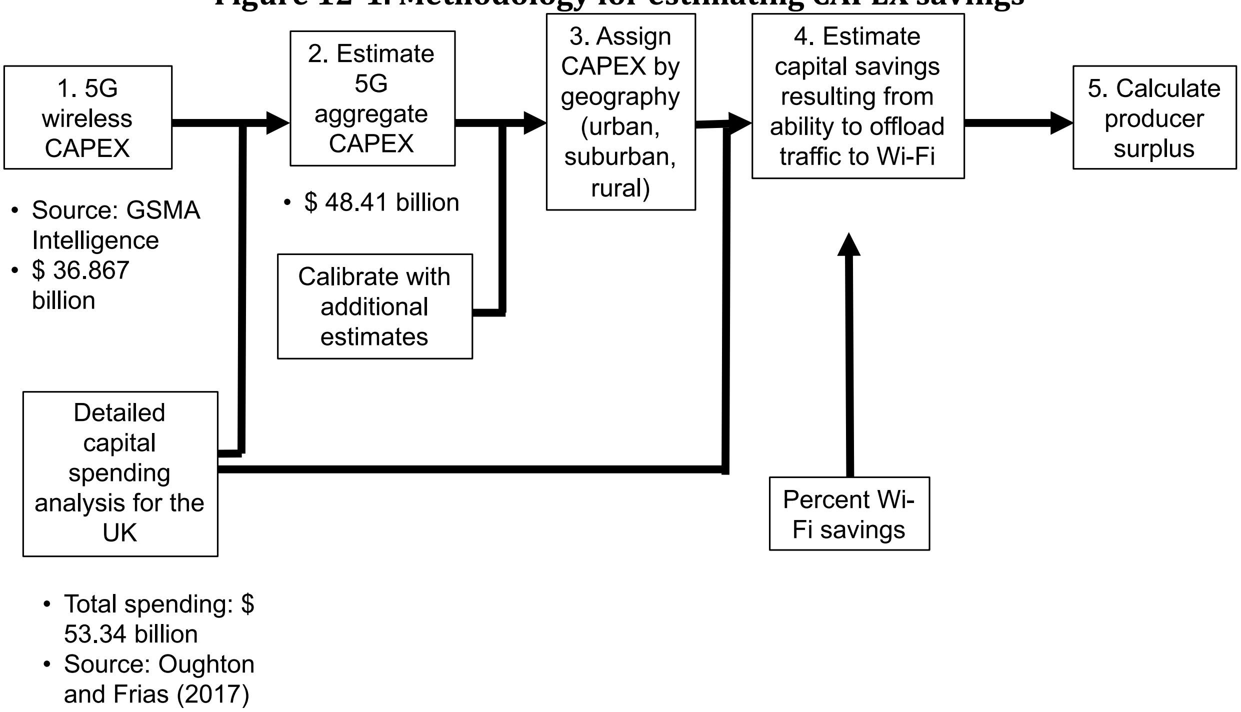
Under such an attractive demand conditions, the decisions to be made in terms of the model of allocating the 6 GHz spectrum (European or US-Korean model) could put Brazil on the path to both meet the needs o local demand and benefitting from the implicit economies of scale derived from advanced markets as well as to increase the opportunity costs of those markets developing first. Additionally, the decision of aligning with a particular model could potentially give Brazil the benefit of developing an export-led industry that could capitalize on foreign demand.

12. ENHANCING THE CAPABILITY FOR CELLULAR OFF-LOADING

5G networks promise faster speeds, lower latency, and greater capacity to mobile users. However, 5G network operators cannot deliver on that promise without robust Wi-Fi networks to carry the majority of that traffic. Cisco estimates that 71% of 5G mobile traffic will be offloaded to Wi-Fi by 2022, even more offload than we have seen from lower speed networks in the past. The availability of spectrum in the 6 GHz band is particularly suited to accommodate this.

The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum in the 6 GHz band, but more importantly, the ability to leverage 160 MHz within a single contiguous channel (see Figure 12-1).

Figure 12-1. Methodology for estimating CAPEX savings



Source: Telecom Advisory Services analysis

The analysis starts with an estimate of 5G deployment costs, absent the Wi-Fi offloading benefit. One approach (Step 1) is to sum wireless CAPEX estimated by GSMA Intelligence for the Brazil between 2019 and 2025: US$36.867 billion[77]. As an alternative approach, we rely on the only known rigorous cost estimation of 5G deployment to date: the one developed by Oughton and Frias (2016) for OFCOM in the United Kingdom. The authors' baseline case estimates a CAPEX of US$53.34 million, of which urban coverage investment amounts only

[77] By 2025, GSMA Intelligence estimates that 5G coverage would have reached 88%

to $890 million, while suburban deployment demands US$7.13 billion, and rural coverage US$45.32 billion (see Table 12-1).

Table 12-1. United Kingdom: 5G Investment

	Town/City (Million)	Population distribution	5G CAPEX ($ billion)	5G CAPEX (%)	CAPEX per POP
Urban (cities >1 million)	19.42	29%	$0.89	1.66%	$45.71
Suburban	36.16	54%	$7.13	13.37%	$197.16
Rural	11.38	17%	$45.32	84.97%	$3,981.22
Total	66.96	100%	$53.34	100%	$796.58

Source: Oughton and Frias (2017). Exploring the cost, coverage and rollout implications of 5G in Britain; Telecom Advisory Services analysis

Using capital investment per POP as a starting point (which does not include spectrum acquisition costs), deployment costs for networks aimed at providing 5G services in Brazil are calculated (Step 2).

Table 3-15. Brazil: 5G Investment

	Population (million)	Population distribution	5G CAPEX ($ billion)	5G CAPEX (%)	CAPEX per POP
Urban (cities>1 million)	84.77	41%	$3.87	2.78%	$45.71
Suburban	95.23	46%	$18.78	13.48%	$197.16
Rural	29.30	14%	$116.66	83.74%	$3,981.22
Total	209.30	100%	$139.31	100%	$442.02

Source: Oughton and Frias (2017). Exploring the cost, coverage and rollout implications of 5G in Britain; Telecom Advisory Services analysis

Considering the cost decomposition of Oughton and Frias (2016), as well as that of the other estimates, the 5G investment under an exclusive licensed spectrum framework will remain significant for suburban (US$18.78 billion) and rural (US$116.66 billion) areas. In this context, unlicensed spectrum becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards, and short-range wireless technologies operating in unlicensed bands. A comparative analysis of CAPEX for 5G base station of pico cell vs. carrier grade Wi-Fi hotspot indicates a cost advantage of the latter amounting to 81%[78]. It should be noted that the Wi-Fi advantage in hybrid networks becomes even more relevant with the 6 GHz spectrum given the hot-spot capacity to handle large volumes of traffic.

We conservatively assume that Wi-Fi will not be critical in sustaining investment in urban areas, but that it will play a significant role in suburban and rural geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, using the estimation of $18.78 billion for suburban coverage and US$116.66 billion for rural coverage, the implementation of Wi-Fi hotspots leveraging 6 GHz will yield

[78] Nikolikj, V. and Janevski, T. (2014). "A Cost Modeling of High-Capacity LTE-Advanced and IEEE 802.11ac based Heterogeneous Networks, Deployed in the 700 MHz, 2.6 GHz and 5 GHz Bands," *Procedia Computer Science* 40 (2014) 49-56.

CAPEX savings of US$8.64 billion[79]. These will be critical in terms of allowing carriers to extend their 5G coverage further into rural geographies.

For purposes of building a consolidated estimate of economic value, it is assumed that cellular carrier CAPEX savings are already accounted in GDP impact of broadband speed.

[79] An additional contribution could include Wi-Fi-like service operating within AFC channels.

13. CONCLUSION

Based on the aggregated results, the allocation of 1200 MHz in the 6 GHz for unlicensed use in Brazil will generate cumulative economic value between 2020 and 2030 reaching US$112.14 billion in additional GDP, US$30.03 in producer surplus (which includes both margins for Brazilian technology suppliers to meet local demand and savings from enterprise wireless use and capital from telecommunications carriers engaged in 5G deployment), and US$21.19 billion in consumer surplus (benefits to consumers in terms of lower cost per Mbps and faster speed) (see table 13-1).

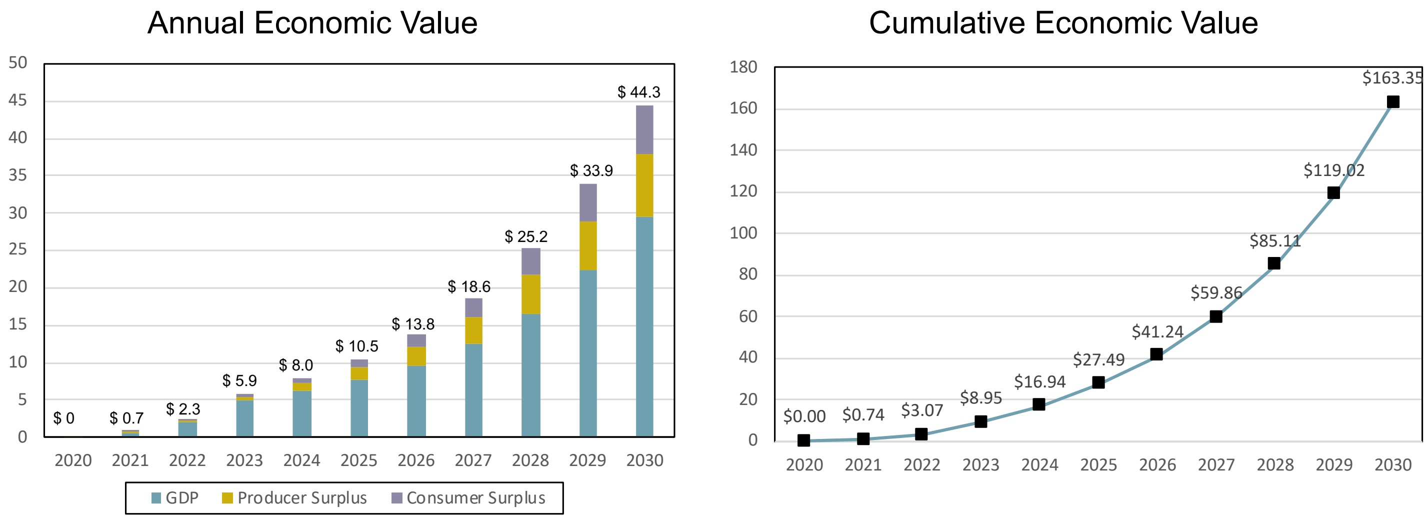
Table 13-1. Brazil: Economic Value of Allocating 1200 MHz in 6 GHz Band (2020-2030) (in US$ billion)

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhance coverage and improve affordability	Improve affordability associated with broadband provision and increasing access sharing in WISP sector **$ 24.91**		Faster speed of access for WISP subscribers **$ 1.21**
Increased speed by reducing Wi-Fi congestion	Benefits of eliminating router bottleneck in high speed connections by increasing speed of in-door Wi-Fi **$ 27.60**		Consumer surplus from increasing speed **$ 16.79**
Wide deployment of Internet of Things	Spillovers of IoT deployment on productivity on key sectors of the Brazilian economy (e.g. automotive, food processing, logistics) **$ 23.59**	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment **$ 10.96**	
Reduction of enterprise wireless costs		Cost reduction of enterprise use of wireless communications **$ 8.41**	
Deployment of AR/VR solutions	Spillovers of AR/VR deployment on the Brazilian economy **$ 29.84**	Margins of ecosystem firms involved in AR/VR deployment **$ 10.22**	
Enhanced deployment of municipal Wi-Fi	Increase in GDP due to enhanced broadband adoption **$ 4.77**		Consumer surplus from faster data download rate as enabled by faster broadband **$ 0.41**
Deployment of Free Wi-Fi Hot Spots	Increase in GDP due to enhanced broadband adoption **$ 1.42**		Consumer surplus from faster data download rate as enabled by faster broadband **$ 2.78**
Aligning spectrum decision with other advanced economies	Potential opportunity of creating a Wi-Fi equipment manufacturing sector (?)	Benefits of economies of scale of aligning Brazil with US (lower equipment prices) **$0.44**	
Enhancing the capability for cellular off-loading		CAPEX reduction derived from offloading wideband wireless traffic to carrier grade Wi-Fi hot spots **$ 8.64** (excluded from total to avoid double counting)	
TOTAL	**$ 112.14**	**$ 30.03**	**$ 21.19**

Source: Telecom Advisory Services analysis

The total economic value increases over time with significant acceleration towards the end of the time period due to the leverage capability of 6 GHz (see graphic 13-1).

Graphic 13-1. Brazil: Economic value of allocating 1200 MHz in the 6 GHz band



Source: Telecom Advisory Services analysis

BIBLIOGRAPHY

ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019

ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020

ABRINT (2018). *Plano de modernização e expansão de acessos com implantação de redes FTTH*

ANATEL. *Plano de Dados Abertos da Anatel*, available at: https://www.anatel.gov.br/paineis/acessos/banda-larga-fixa

Benkler, Y. (2012). "Open wireless vs. licensed spectrum: evidence from market adoption". *Harvard Journal of Law & Technology*. Volume 26, Number 1 fall 2012

Blackman, J. (2020). "UK to release 6 GHz and 100 GHz spectrum for Wi-Fi in smart homes, offices, factories". *Enterprise IoT insights* (January, 27).

BNDES (2017). Estudo Internet das Coisas: um plano de ação para o Brasil.

Bohlin, E. and Rohman, I. (2012). *Does Broadband Speed Really Matter for Driving Economic Growth? Investigating OECD Countries?* Available at SSRN: http://ssrn.com/abstract=2034284 or http://dx.doi.org/10.2139/ssrn.2034284. , 2013

Calabrese, M. (2013). *Solving the "Spectrum Crunch": Unlicensed Spectrum on a High-Fiber Diet*. Washington, DC: Time Warner Cable Research program on Digital Communications.

Carew, D., Martin, N., Blumenthal, M., Armour, P., and Lastunen, J. (2018). The potential economic value of unlicensed spectrum in the 5.9 GHz Frequency band: insights for allocation policy. RAND Corporation (Rand study).

Carter, K. (2006) "Policy Lessons From Personal Communications Services: Licensed Vs. Unlicensed Spectrum Access," *CommLaw Conspectus* 93

CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), *Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019*

Cisco (2017*). Cisco Visual Networking Index: Global Mobile data Traffic Forecast Update, 2016- 2021*. Retrieved from https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html.

CSI Market Inc *: Industry Profitability ratios;.*

CompTIA (2016). *Sizing up the Internet of Things*.

Cooper, M. (2011). *The consumer benefits of expanding shared used of unlicensed radio spectrum: Liberating Long-Term Spectrum Policy from Short-Term Thinking*. Washington DC: Consumer Federation of America.

Crawford, S. (2011). *The FFC's job and unlicensed spectrum – Waldman report*. Statement to the FCC.

Ebbecke, Ph. (2019). *Road to 6 GHz in Europe*. Presentation to WLPC Prague 2019

Ford, G. (2018). *Is Faster Better? Quantifying the Relationship between Broadband Speed and Economic Growth*. Phoenix Center Policy Bulletin No. 44.

Frontier Economics (2018). *The economic impact of IoT: putting numbers on a revolutionary technology*

Frost & Sullivan (2021). *Industrial Internet of Things (IoT) revenue in Brazil (2016-2021).*

Grimes, A., Ren, C., and Stevens, P. (2009). *The need for speed: Impacts of Internet Connectivity on Firm Productivity.* MOTU Working Paper 09-15.

Hausman, J. (1997). *Valuing the Effect of Regulation on New Services in Telecommunications*. Brookings Papers on Economic Activity, Economic Studies Program, 28(1997-1), pp. 1- 54.

Hazlett, T. (2005). "Spectrum Tragedies - Avoiding a Tragedy of the Telecommons: Finding the Right Property Rights Regime for Telecommunications" 22 *Yale Journal on Regulation*

Hetting, C. (2019). "Europe's process to release 6 GHz spectrum to Wi-Fi on track, expert says", *Wi-Fi Now* (June, 2).

Hetting, C. (2020). "South Korea could become Asia's first 6 GHz nation". *Wi-Fi News* (June, 27).

IBGE, *Pesquisa de Informações Básicas Municipais* - 2014 data

Katz, R. (2014a). *Assessment of the economic value of unlicensed spectrum in the United States*. New York: Telecom Advisory Services. Retrieved from: wififorward.org/resources

Katz, R. (2014b). *Assessment of the future economic value of unlicensed spectrum in the United States*. New York: Telecom Advisory Services. Retrieved from: wififorward.org/resources

Katz, R. (2018). *A 2017 assessment of the current and future economic value of unlicensed spectrum* . Washington, DC: Wi-Fi Forward. Retrieved from: wififorward.org/resources

Katz, R. and Callorda, F. (2018). *The economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the Americas*. Geneva: International Telecommunication Union. Retrieved from: http://handle.itu.int/11.1002/pub/81377c7f-en

Katz, R. (2018). *The global economic value of Wi-Fi 2018-2023* . New York: Telecom Advisory Services. Retrieved from: *wi.fi.org*

Katz, R. (2020). *Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands*. Washington, DC: Wi-Fi Forward. Retrieved from: wififorward.org/resources

Kongaut, Chatchai; Bohlin, Erik (2014). *Impact of broadband speed on economic outputs: An empirical study of OECD countries* , 25th European Regional Conference of the International Telecommunications Society (ITS), Brussels, Belgium, 22-25 June 2014,

Liu, Y-H; Prince, J., and Wallsten, J. (2018). *Distinguishing bandwidth and latency in households' willingness-to-pay for broadband internet speed*.

Mack-Smith, D. (2006). *Next Generation Broadband in Scotland* . Edinburgh: SQW Limited).

Marcus, S. and Burns, J. (2013). *Study on Impact of Traffic off-loading and related technological trends on the demand for wireless broadband spectrum: a study prepared for the European Commission DG Communications Networks, Content & Technology.* Brussels: European Union

Milgrom, P., Levin, J., & Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion paper No. 10-036, p. 2. Retrieved from https://web.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf.

Nevo, A., Turner, J., and Williams, J. (Mar. 2016). "Usage-based pricing and demand for residential broadband", *Econometrica*, vol. 84, No.2, p. 441-443.

Oughton and Frias (2017). *Exploring the cost, coverage and rollout implications of 5G in Britain*

PWC (2019). *Seeing is believing: how virtual reality and augmented reality are transforming business and the economy*

Rosston, G., Savage, S. and Waldman, D. (2010), *Household demand for broadband internet service* . Available at http://siepr.stanford.edu/system/files/shared/Household_demand_for_broadband.pdf.

Stevenson, C. et al. (2009). "IEEE 802.22: The first cognitive radio wireless regional area network standard," *Communications Magazine IEEE* 47 (1): 131.

Suarez, M. (2020). *Unlicensed spectrum access in the 6 GHz band. Presentation to ANATEL*

Thanki, R. (2009). *The economic value generated by current and future allocations of unlicensed spectrum*. United Kingdom: Perspective Associates

Thanki, R. (2012). *The Economic Significance of License- Exempt Spectrum to the Future of the Internet.* London

Yonhap (2020). "Unlicensed frequency band to boost Wi-Fi speed, smart factory penetration: ministry", *The Korea Herald*, (June, 27).

WISPA (2020). *Letter to the FCC Commissioners* (March 5).