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Different regulation paths towards cognitive radio technologies: Cases of Finland and Chile

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Different regulation paths towards Cognitive Radio technologies:

Cases of Finland and Chile

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Abstract

Radio spectrum regulation progresses in parallel on global and local levels. The European Union harmonizes the spectrum in its member countries, defining the type of service and the technology to be used. In the Americas, standard and infrastructure competition struggles to use the spectrum for mobile services. This paper develops a framework to analyze country regulations, its status and future development paths. Chile and Finland present market and demographic similarities along with regulatory and cultural differences. The paper analyzes both countries, trying to summarize lessons for future spectrum regulation in a scenario of introduction of Cognitive Radio technologies. We observe that the development of these technologies will depend on the market structure of each country; in concrete, on the level of spectrum decentralization and on the level of industry openness.

1 Introduction

Spectrum regulation is nowadays one of the most agile areas of country regulation. The continuous growth in service demand and the constant emergence of new technologies pushes countries' regulators to optimize their spectrum usage by constantly updating their spectrum policy. Even though most of the countries constantly adopt ITU global recommendations for spectrum management, regulation is affected for country specific decisions based on historical, cultural, geographical, political and market issues.

Several studies (ITU-R M.2078, 2006; Cisco, 2009; Faulhaber, 2009) forecast that mobile service demand will exceed spectrum capacity in the following years. In fact, different consultancy groups forecast a growth in transmission capacity need, which goes from 20 to 45 times in 5 years from 2009 to 2014 (FCC, 2010). Even though mobile service forecasts highly vary depending on the country and city, the mobile demand has increased exponentially in the last years. Additional spectrum should be released and licensing mechanism should be developed to optimize the spectrum usage. From a regulation perspective, spectrum needs a more flexible, market-based management. In this context, the idea of a "Cognitive Radio" (CR) emerged, getting high attention from the academic and industry world. After this concept was first introduced (Mitola, 2000), it

has increased in popularity during the last years, when industry and research centers start to develop first Cognitive Radio enabling technologies.

Cognitive Radio concept was originally introduced by Joseph Mitola in his doctoral thesis as follows: "A radio frequency transceiver designed to intelligently detect whether a particular segment of the radio spectrum is in use, and to jump into (and out of) the temporarily unused spectrum very rapidly, without interfering with the transmission of other authorized users." (2000) Mitola incorporated the idea of a cognitive cycle, where the mobile terminal should: "observe, orient, plan, learn, decide and act". Later ITU (2009) gave to cognitive radio a system definition: "a radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained."

This concept adds intelligence to mobile devices and pushes further competition and innovation to the mobile services through a more optimal spectrum use. From a network perspective, spectrum management functionalities are increased in the terminal to optimize spectrum usage. However, in practice, network equipment vendors need to develop CR enabling technologies in tight cooperation with terminal vendors to get a whole working system. Even though CR technologies are attractive from many perspectives, in practice they demand big changes to the whole ICT ecosystem and must be orchestrated by the local regulator and by international standard organizations.

Cognitive Radio has been studied from many perspectives. From an economic perspective, many authors apply a game theoretical approach to describe market equilibriums through different cooperation or noncooperation scenarios. A recent state of the art overview of the game theoretical analysis in Cognitive Radio can be found in Wang, Wu and Liu (2010). We focus at a market level, not at a system engineering level. For example, Ber, Klemetilä, Uusitalo and Wijting (2010) performed a 3 player oligopoly model using Stackelberg game based on UK's data. They conclude that Cognitive Radio introduction may generate further income for all 3 players under all analyzed scenarios, even though that high uncertainty exists on the timing. Sengupta and Tauman (2011) modeled a Cournot game to calculate social welfare. Mähönen and Petrova (2008) modeled cognitive radio as a non cooperative game. Also Elias, Martignon, Capone and Altman (2011) modeled through a non cooperative game the interaction between the primary and the secondary users. Wynn, Ben and Cao (2009) used instead a cooperative game. From a market perspective, Nguyen, Zhou, Berry Honig and Vohra (2010) analyze the impact of additional unlicensed spectrum on the US TVWS case (secondary versus commons use). Huang, Berry and Honig proposed a market mechanism using Vickrey-Clarke-Groves (VCG) auction theory considering technical constraints such as interference (Signal to noise-plus-interference ratio and interference temperature).

Despite of the benefits Cognitive Radio promise, high uncertainty exists on the way this technology will be introduced into different mobile markets. Plenty of scenario analysis has been done. As an example, we mention the scenarios used by the European project FARAMIR, which have been used by other authors. These scenarios emphasizes the concepts of primary versus secondary spectrum usage (one user has priority as compared with another user) and cooperative versus opportunistic usage (operators' coordination versus the uncoordinated use).

Others studies focus on business models and future evolution. Ballon and Delaere (2009) study the future business models for a flexible spectrum scenario. Smura and Sorri (2009) and Casey (2009) define 4 scenarios for the evolution of the mobile telecom industry, according to the degree of vertical integration and to the decentralization of spectrum management and radio access provisioning.

In addition, many regulatory issues may still arise when deploying Cognitive Radio technologies in a certain country. For example, a study made for Ofcom (Qineti, 2007) summarizes some open issues related to both technology and business issues: liberalized spectrum environment (how to enable secondary licensing), standardization of interfaces, standardization work, spectrum database (the role of a 3rd party in the spectrum trading), convenience of dedicated spectrum for CR control and Software based spectrum policies. In theory, spectrum liberalization can achieve higher spectrum efficiency, but in practice no developed country has yet been successful in introducing market-based spectrum mechanisms. Guatemala (ITU, 2010) is a successful example of a developing market, which may not necessarily apply for developed market. Liberalized spectrum policy deployed by developed markets (such as Denmark, Australia or New Zealand) has not brought visible results as compared with other similar markets (Falch, Tadayoni, 2004; Ministry of Economic Development of New Zealand, 2005; ITU, 2006).

From a general perspective, Cognitive Radio may liberalize the spectrum adding, at the same time, additional complexity, since it demands further coordination between industry players. On the other hand, some authors argue that promoting competition through a non optimal regulation can affect negatively the industry and the individual investment (Grajek, Röller, 2009). Freytag and Winkler (2004) also point out the problems of overregulation in telecommunications showing the advantages of a self regulated environment.

This paper develops a framework to analyze country policy status and possible future paths toward Cognitive Radio technologies. The cases of Finland and Chile are analyzed. This review is complemented by expert interviews, from analyzed countries' regulators and stakeholders. Finally, the paper highlights some issues for future spectrum regulation analysis.

The rest of the paper is organized as follows: Chapter 2 presents the framework to be used in the spectrum policy analysis of this paper. Chapter 3 applies the framework to the cases of Chile and Finland. Chapter 4 summarizes the main achievements and conclusions.

2 Framework for spectrum policy analysis

2.1 Towards technology and service neutrality

Telecom regulators can assign a frequency band for the usage of a certain service: public mobile voice or data, private-amateur usage and collective usage, for example. However, in practice, the frequency limits the technology and service election. Nevertheless, the latest technologies such as LTE are enabling a more flexible use of frequencies. In addition, the regulator can define the technology for a frequency band or can let the technology undefined for the free choice of the market. In the 2G case, Europe defined GSM for mobile services, while Americas allowed standard competition.

Nowadays, regulators throughout the world are going toward service and technology neutrality, to allow the market to choose the technology to offer converged mobile broadband. Table 1 summarizes different spectrum regimes.

Frequency allocation	Technologies standardization	Usage rights
Harmonized spectrum (No Service Neutrality)	Standardization (No Technology Neutrality)	Property rights: exclusive
		Property rights: with easements
		Collective use
	Techno neutrality (No Standardization)	Property rights: exclusive
		Property rights: with easements
		Collective use
Service neutrality (No Harmonization)	Techno neutrality (No Standardization)	Property rights: exclusive
		Property rights: with easements
		Collective use (e.g. WiFi)

Table 1: Different spectrum regimes according frequency allocation, technology standardization and usage rights (source: Chaduc, Pogorel, adapted)

2.2 The Phase Diagram for mobile telecom regulation

To analyze the mobile telecom regulations of different countries, the paper develops a Phase Diagram, based on previous scenario analysis done by Smura and Sorri (2009) and Casey (2009). It describes the type of regulation by analyzing the market structure achieved through policy decisions. The two explaining factors are the level of openness of the industry and of level of decentralization of the spectrum. We assume the radio spectrum is the main natural resource, which enables mobile communication. These factors explain the type of regulation by looking at the mobile telecom industry, from its structure and spectrum policy perspectives.

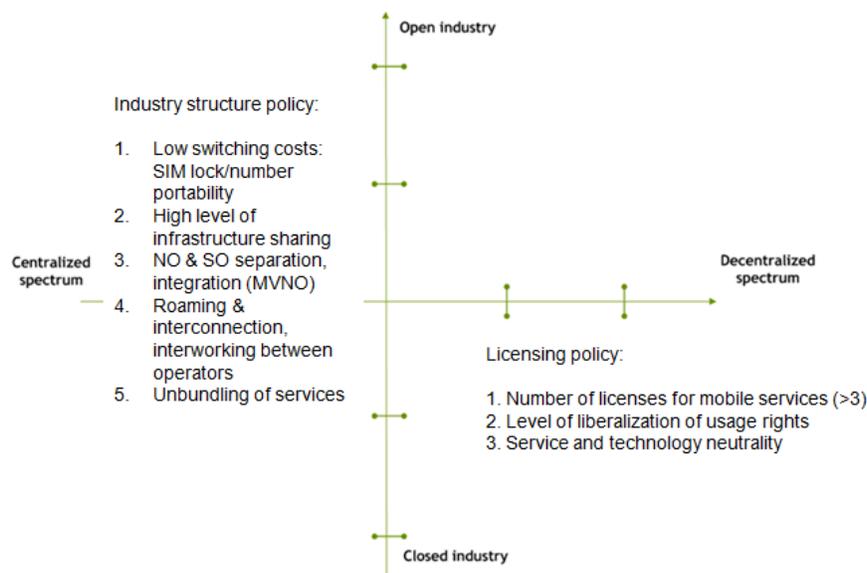


Figure 1: Phase Diagram for the analysis of country spectrum regulation

In Figure 1, the x-axis describes the spectrum decentralization, which depends on licensing policy decisions, mostly taken by the regulator, such as number and type of mobile licenses (the average of mobile operators for OECD countries is 3,4 and concentration index HHI is 3,6 for market share), technical and service neutrality policy and level of liberalization of spectrum rights (exclusive versus property right or commons). The y-axis describes the openness of the telecom industry, which is driven by industry structure policy decisions, due to regulation or free cooperation between players, impacting the market structure. These are the following: customer switching costs (such as SIM lock and number portability), infrastructure sharing and cooperation between operators, separation of Network and Service Operators (e.g. existence of virtual and service operators), interworking between operators (roaming & interconnection agreements) and unbundling level of services. Cognitive Radio introduction increases openness, i.e. encourages industry players to cooperate with each other and decentralizes the spectrum, i.e. enables new players to use the spectrum and generates new service innovation while optimizing the use of the spectrum. If the spectrum is decentralized and the industry is closed, the market presents many

independent operators without much cooperation (e.g. current WLAN scenario with commons regime). When the spectrum is centralized, the industry is driven by an oligopoly (even a duopoly in some cases), which can be open (with cooperation) or closed (without cooperation). In the majority of mobile markets, a centralized scenario dominates with command and control regime.

This diagram shows what kind of policy a country is practicing, through the analysis of the resulting mobile market structure. In addition, we map most relevant economic theories to the phase diagram. At the left side of the diagram (Figure 1), oligopolies can be modelled using e.g. a game theoretical approach. On the other side, the Coase theorem and a Schumpeterian view on innovation may be useful to analyze a scenario, where industry is open and spectrum policy is decentralized.¹

The Coase theorem states that the free assignment of resources will be optimal and the government intervention will only worsen the social welfare if: a) property rights are well defined b) no existence of transaction cost between parties. Thus, Coase introduced the convenience of a market based property right regime in “The problem of social cost”, and further analyzed its impact in the case of spectrum policy, where he introduced the first time the idea of a market based spectrum auction already in 1959. From those years technology has changed radically, but the theory behind the radio spectrum management is still the same. For example, Hazlett et al. (2001) explores the clarity of mind of Coase in its theorem and the impact of his thoughts in current spectrum policy. Other authors have analyzed spectrum issues based on the Coase theorem at conceptual level (Guzzini, Palestrini, 2009; Crocioni, 2009; Lee, Sabourian, 2006).

On the other hand, Schumpeter presented the idea of a “creative destruction” to explain how innovation happens in technology from an evolutionary perspective. Schumpeter supported the idea that innovation is coming from smaller companies rather than bigger ones, despite bigger companies may have higher market power to invest in innovation. From this perspective, Cognitive Radio may produce a suitable environment for new service innovation, both coming from new entrants and incumbent players. From this perspective, a Schumpeterian view of competition may not only enable a price competition, but also new service innovation and cooperation between players (Atkinson, 2010; Andersen, 2007; Krafft, 2008).

From a Coase theorem perspective, the value of the transaction is increased when the transacted services or goods are diverse. In other words, the value of the transactions increase if the firms involved in the transactions are diversified (they have different costs and services). Furthermore, in an industry where the competition happens in the service rather than in the infrastructure, a technology which enables transactions of transmission capacity may increase the level of diversification, decrease entry barriers and increase the entrance of new firms.

¹ We also reviewed the following authors and theories for this analysis: Stigler, A. Smith, tragedy of commons, Pigout, public choice, Walras, Braeutigam and self regulation (more information on economic theories in the book of Tarziján and Paredes, 2011; paper on self regulation of Freytag, A; Winkler, K. 2004)

In the past years, many country regulators analyzed how to optimize the use of the digital dividend or how to reform the spectrum or introduce secondary market (Hazlett, Muñoz; 2008). Others suggested an opportunistic usage of unlicensed band by mobile operators (FCC; 2004). From a Coasean perspective, the value of the transaction increase when players are diversified. This supports the idea that technological innovation is more valuable when it allows the entrance of new players.

3 Analysis of the Chilean and Finnish spectrum policy

This section applies the phase diagram framework to analyze spectrum country regulation in Chile and Finland. We choose two countries which resemble in terms of mobile market competitive environment but however are different enough in macroeconomic, cultural and regulatory perspectives. In terms of telecom market competitiveness we see both countries having good achievements at their regions. In fact, in the Networked Readiness Index, Finland ranks 3 and Chile 2 within their income groups; high income and upper middle income respectively (The Global Information Technology Report 2010-2011). In the general ranking, Finland ranks 3 and Chile leads Latin America ranking 39 (without considering Barbados, which ranks #38). Both countries show high mobile penetration and coverage while presenting a competitive legal environment for internet and telephony. Additionally, individual, corporate and governmental usage of the ICT technologies is good enough. Chile still has improvement possibilities in intellectual property rights, and in tariffs competitiveness (fixed and mobile). In price comparison, Finland ranks 21 while Chile ranks 53 in mobile tariffs. In fixed broadband internet, Finland ranks 43 and Chile 100 (See appendix B). Also, in both markets, mobile market share is divided into 3 main mobile operators. In addition, both countries are geographically quite isolated from boundaries' interference. On the other hand; culture, location (ITU region) and regulation differs from each other enough to be comparable. In terms of population, both have similar density, Chile having much higher concentration in its capital than Finland.

Analyzing them through the phase diagram framework, we aim to understand how different spectrum regulation can be and how they should face the future changes of the telecom ecosystem.

3.1 Evolution of the spectrum policy

3.1.1 Historical development

The Figure 2 and 3 show a summary of the evolution of regulation practiced in both countries in the mobile industry. Decisions taken in the past influence the current regulation status and future decisions. In Chile, the two new entrances affect the market structure and determine currently very much the competition. In Finland, the vertical competition and the horizontal concentration has determined the spectrum policy and the dynamic of the industry.

At follows we present the evolution of analyzed countries' policy with some historical information.

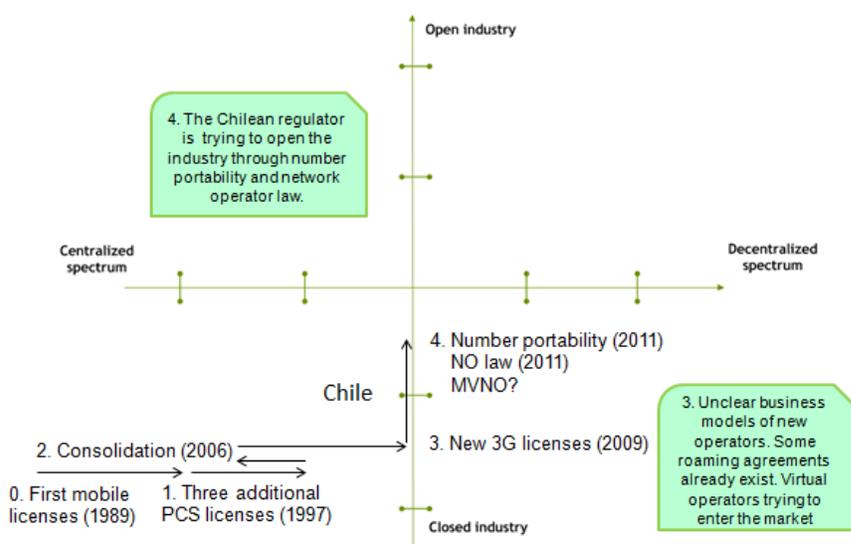


Figure 2: evolution of mobile industry regulation of Chile in the Phase Diagram.

From the year 1982, the Chilean legislation has ensured a free and equalitarian access to spectrum resources decided under technical parameters (Sierra, 2006). Chilean telecom regulation law from years 82 and 83 is still in force, even though constantly updated (e.g. Subtel, Decreto 127 and 959). The Chilean Communication Regulatory Authority, Subtel (Subsecretaría de Telecomunicaciones) gives free concessions to everybody requiring spectrum licenses (Paredes, 2000). In the case of mobile services (spectrum scarcity), a beauty contest is organized to maximize network coverage and time of network rollout. In practice, beauty contest is the main licensing method for mobile services. In case of draw, an auction of one round and closed envelope is performed between the competing players. Chile follows ITU's global directions for region 2 as much as possible (Subtel interview, 2011).

Chile's first 2G licenses were granted in 1989 through a beauty contest, which favored the coverage of isolated areas of the country. Licenses were technologically neutral and service

harmonized (command and control). Reselling of the “entire” license with all its obligations was allowed. In 1997, 3 additional licenses were given to operators through a new beauty contest. After a market consolidation in 2006, the 3 current mobile operators emerged. Subtel has the impression that beauty contest played a key role in achieving high mobile service coverage considering a geography, which is highly irregular (Subtel interview, 2011).

The Chilean regulation is service-harmonized in the allocation of frequencies. The “intermediate” service category was used initially multicarrier-based long distance telephony. Nowadays, it is used for mobile converged services, which in practice offer service neutrality. Thus, Subtel prefers to reinterpret the law rather than to change it to avoid market uncertainty (Subtel interview, 2011).

Chile’s position in the spectrum decentralization versus industry openness is shown in Figure 2. Subtel tried to push the entrant of virtual operators in 2006 (Subtel, Resolución Exenta 1667), without achieving concrete results until the moment (Subtel interview, 2011). Subtel enabled recently two new mobile operators, setting 60MHz -spectrum cap in the licensing of 90MHz of the 1.7 / 2.1 GHz band in 2009. The original beauty contest finished with an auction between VTR and Nextel (getting 30 MHz and 60MHz respectively). In terms of vertical integration, Chilean operators integrate network and service operations and practice data and voice bundling. Additionally, infrastructure sharing of Chilean operators is still very limited. However, a new law is pushing operators to cooperate in infrastructure sharing (Subtel interview, 2011). In addition, the deployment of number portability and the unlocking of terminals (2011) may favor new entrants. In fact, during 2012, two new MVNOs started in the Chilean market (Virgin and Telsur).

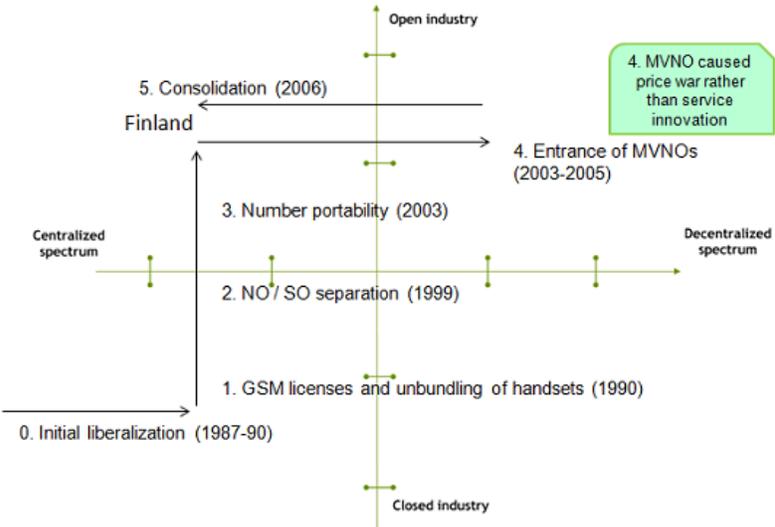


Figure 3: evolution of mobile industry regulation of Finland in the Phase Diagram.

The Finnish Ministry of Transport and Communication is the policy making body and FICORA (Finnish Communication Regulatory Authority) is the regulator (making and applying the law falls

under different entities). Finland has a long history of private multi operators (Finnet Association was gathering small private telephone companies from the year 1921). Spectrum allocation policy falls under ITU recommendations for region 1 and European Commission decisions for EU countries.

In Finland, beauty contest has been the main licensing mechanism for mobile services. The 3.5 GHz band some has been assigned through “first come first served” mechanism for local WiMAX services. In 1987, the telecommunications law allowed competing licenses for mobile operators. In 1990, two new national GSM licenses were granted through a beauty contest. Sonera, the former state telecom company, had already by law the right to provide service without license. As a result, in 1994 the Finnish mobile market was fully liberalized, while at the EU level liberalization was fully implemented in 1998 (Ministry of Transport and Communication, Finland, 2003).

Finland was one of the first countries in licensing 3G spectrum in 1999 in the 2 GHz band for UMTS technology (Figure 3). Beauty contest was still used. In 2000, the Finnish regulator gave UMTS networks operators roaming obligation. Finland was a pioneer in the telecom market and during many years a leader in mobile penetration. The Finnish telecom policy has traditionally relied strongly on market competition rather than imposing high coverage obligation to operators. A key issue has been the active role of FICORA; which practiced successfully the unbundling of services and an early number portability in 2003. Additionally, the separation of network and service operators (1999) enabled the entrance of virtual operators in 2003 (Figure 2).

FICORA has been an active regulatory body, pushing price level (mobile voice and broadband) to the lowest of the EU (FICORA, market review 1/2009) through service and industry unbundling. With time, FICORA preferred to allow handset bundling for 3G services (2006) and incumbent operators bought virtual operators maintaining them as brand operators.

Recently, FICORA organized a 4G auction for the 2.6 GHz band to get the experience of market based assignment methods. It achieved very low prices and similar final assignment than in previous beauty contest (FICORA interview, 2011). In addition, these last licenses were service and technology neutral and opened the possibility of spectrum reselling (through the mediation of FICORA). Also, Finland is allowing operators to use newer technologies in their technology harmonized bands (spectrum refarming). In practice, license prices are set in Finland to recover the administrative costs (MPS 60 Explanatory Memorandum, 2009).

Finland has done early efforts to open the industry. The Finnish regulator forbade handset bundling for 2G services, but allowed it for 3G services. By law, service operators are separated from network operators (1999), and infrastructure cooperation is commonly used. In addition, Finland was one of the first countries in implementing successfully the number portability (2003). However, most Finnish virtual operators have not survived in the market and after market consolidation (Figure 3); market share is again divided into 3 main players.

Country	Frequency band	Date of award	Price per MHz/pop (USD)
Chile	1.7 / 2.1 GHz	9/2009	0.0113
Finland	2.5 GHz	11/2009	0.00465

Table 2: Price per MHz per population in the last Finnish and Chilean auctions (GSMA, 2011). Both prices are low as compared with other markets, where auctions have prevailed.

Both countries are analyzing the allocation of the digital dividend. The WRC-2012 suggested the exclusively allocation of part of this band to mobile operators (700MHz band or digital dividend 2). Finland already switched off the analog television in 2007. In Chile, most of the UHF band was intentionally set as “free”, when unused TV licenses were not renewed in 2000. The switch off of analog television will provide additional spectrum in future. In general, TV white space availability depends on the country.

Finally, technology paths of Chile and Finland differ from each other. While Finland practiced technological harmonization, Chile allowed a heterogeneous deployment of the 2G mobile networks (GSM, CDMA and TDMA D-AMPS). However, after market consolidation, all the mobile operators shifted to GSM to continue through 3GPP’s standards. In other words, while in Finland, the regulator chose GSM standard, in Chile the market chose the same standard. Time has shown that GSM harmonization was faster and cheaper for introducing competition, but from a Chilean perspective technology neutrality had lower risks at the time when operators built 2G mobile networks with different technologies (Subtel interview, 2011).

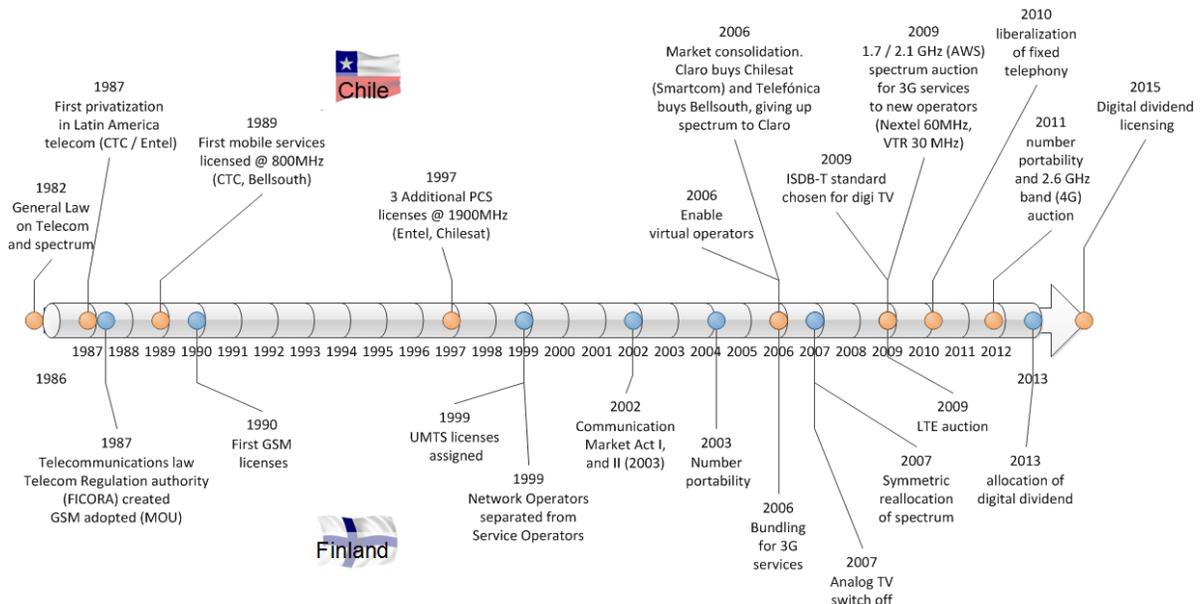


Figure 4: Timeline of spectrum regulation milestones for Chile and Finland

3.1.2 Description of current policy status and mobile markets

Chilean and Finnish policy differs in the way spectrum is assigned between mobile operators. Finnish assignment is symmetric (Figure 5). This means that in practice each band is divided into three “pieces” of equal size. With this purpose, the Finnish regulator decided in 2007 to reassign the spectrum between the three existing operators in a symmetric way, to give to each player the same possibilities to compete (FICORA interview, 2011). Chilean spectrum is divided between operators in an asymmetric fashion. In fact, equally divided frequency lots of each band are given to operators in open competition. The regulator levels the concentration of spectrum through a spectrum cap (60 MHz), which in practice allows greenfield operators. As a result, Chile has at the moment 5 operators with different amount of spectrum and asymmetrically assigned, while Finland has 3 operators with the same amount of spectrum assigned symmetrically. Thus, Chilean spectrum is less concentrated than the Finnish (Chile has a spectrum HHI index of 2.08 versus Finland’s 3.27).

Table 2 summarizes the current status of the spectrum policy according to the parameters analyzed in the phase diagram.

	Chile (cap= 60MHz)	Finland (symmetric)	 Chile	 Finland
700 MHz	Digital dividend			
800 MHz		Digital dividend	 Entel	 Sonera
850 MHz	 25  25		 Telefonica	 Elisa
900 MHz		 23,3  23,3  23,3		
1800 MHz		 50  50  50	 Claro	
1900 MHz	 30  30  30  30			 DNA
1.7 / 2.1 GHz	 30  30  30		 VTR	
2 GHz		 13,3  13,3  13,3		
2.4 GHz	License free*	License free*	 Nextel	
2.6 GHz	4G licensing	 46,7  46,7  46,7		
5.0 GHz		License free		
5.8 GHz	License free*	License free*		

* ISM band

new

Figure 5: the different allocation and assignment of spectrum for mobile operators in Chile and Finland. Allocation depends on the ITU region. Assignment depends on the country (ECO, 2001; FICORA, 2010; Subtel, 2011; ITU, 2002; Sierra, 2006)

	Finland	Chile
Switching cost (SIM lock, number portability)	Low	Low
Infra sharing	High	Low
NO/SO separation	Yes	No
Roaming, interconnection	Yes	Yes
Unbundling level of services	High	Medium
Number of players	3 + small MVNOs	5 + 2 new MVNOs
Liberalized user rights	Reselling in 4G licenses	Command & Control
Service & tech neutrality	In 4G licensing	In 4G licensing

Table 3: Summary of the current status of each country

In terms of spectrum regime, both countries are going toward service and technology neutrality. Finland started with a harmonized spectrum regime and is changing towards service and technology neutrality. On the other hand, Chile deployed a technology neutral spectrum policy from 2G licensing and is allowing service neutrality in the last licensing processes. In addition, the last Finnish auction enabled spectrum reselling for 4G licenses, even though until the date no reselling has happened (FICORA interview, 2011). Chilean new licensing processes are still arranged using beauty contest. The Chilean regulator is interested in exploring new market based mechanism in the future, but the law requires changes to allow new mechanisms.

Table 3 summarizes the available amount of spectrum in both countries.

	Mobile operators	Available spectrum for mobile operators	Available spectrum per inhabitant
Chile	5	260 MHz	15,3 Hz (17 millions)
Finland	3	340 MHz	61,8 Hz (5.5 millions)

Table 3: shows the availability of spectrum for mobile users (Hz per inhabitant)

The Chilean telecom industry is vertically integrated. Chilean regulator allowed mobile service bundling to terminals and SIM cards locking to phones. Competition has mainly been driven by coverage and capacity (infrastructure competition), and operators do not separate the network and service businesses. However, Chile is doing simultaneous efforts to open the industry. The introduction of number portability (2001), the unlocking of SIM cards (2011) and a new law allowing the networks operators (2012) will increase the cooperation between different mobile operators. In addition, the law on infrastructure sharing (2012) and the new entrances will push entry barriers down. However, Chilean operators still integrate the network and service businesses.

In Europe, network operators are required from 1999 to publish their wholesale price to sell network capacity to any service operator at a nondiscriminatory price. As a result, MVNOs in Finland had an important role in driving a price competition (Kiiski, 2006). In addition, the Finland regulator has been quicker to push competition in the telecom industry by pushing down entry

barriers. In fact, Finland has many years of experience of mobile service unbundling and cooperation of infrastructure.

In a general perspective, the Chilean telecom regulation is characterized by pushing a competition based on infrastructure, technological neutrality and asymmetrical spectrum allocation through spectrum cap. The Finnish regulation presents a competition based on service (higher cooperation in infrastructure), symmetrical allocation of spectrum between three incumbent operators and technological harmonization. These differences impact the industry structure, and they are related to the way each country balance the market regulation and the market freedom (See appendix A for a comparison table).

As of 2011, the current mobile market picture looks at follows. Both countries have 3 main mobile network operators with similar market share (Finland: Elisa 39% - TeliaSonera 36% - DNA 23 %. Chile: Telefónica 42% - Entel 38% - Claro 20%, data from regulators).

In the broadcasting industry, Finland has only one broadcasting network managed by Digita, a private company regulated by FICORA, which transmits the content for TV channels. In Chile, each TV operator has its own network.

Finally, Finland has a mobile churn rate of 10% (Numpac, 2011) while Chile has a churn rate of about 20% (estimation by V. Marianov, 2011). Thus, Finnish postpaid market has a lower churn rate than Chilean prepaid market (which is more price-sensitive). Lower mobile prices in Finland as compared with Chile (Table 4) are due among others to the following reasons: price war caused by virtual mobile operators, price war caused by unbundling of mobile services and fast and successful deployment of number portability.

Average Price of service	Finland	Chile
Per minute per SMS	0,07 EUR	0,15 EUR (= 100 CLP)
Data suscription per month	10 EUR *	15 EUR (= 10,000 CLP) *

*Connection speed of 1GBps

Table 4: comparison of average prices per service (source: operators' websites November 2011)

3.2 Future evolution

3.2.1 Toward market based spectrum regulation

Chile and Finland have different starting positions in the path toward spectrum liberalization, because their market structures are characterized by different historical decisions. This creates

path dependence for future regulatory decisions. The Finnish telecom industry is already quite open, and therefore Cognitive Radio may allow spectrum decentralization. Nowadays, Finland lacks apparently strong reasons to decentralize its spectrum assignment, considering that mobile competition is high and virtual operators were not able to survive. On the other side, Chile recently enabled new spectrum owners in the mobile market. A market based spectrum policy may further decrease entry barriers, through e.g. spectrum secondary market and increase the level of cooperation between existing players. In both cases, we see that the current market structure as a starting point to analyze the benefits and costs of the Cognitive Radio introduction.

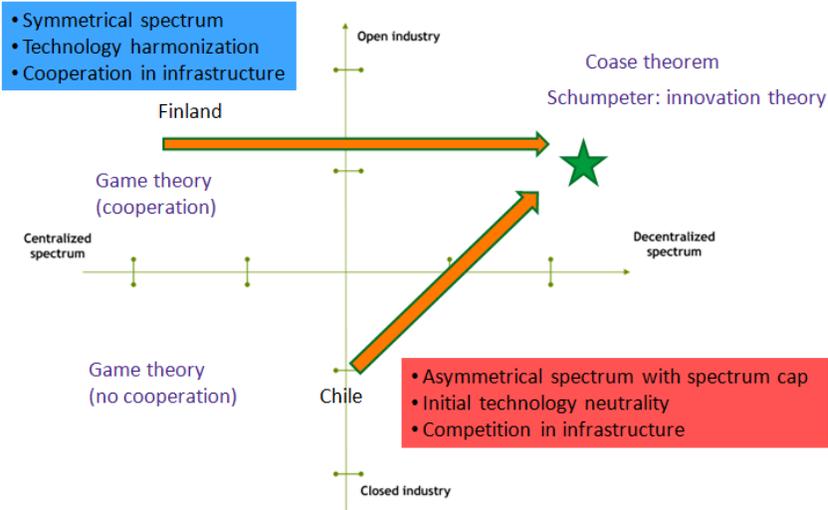


Figure 6: Chile and Finland space diagram with the path to a scenario with open industry and decentralized spectrum policy. In addition, the space diagram shows related economic theories.

From an economic perspective (Figure 6), Chilean and Finnish current competitive oligopolies may be described using game theory (with or without cooperation), and may be analyzed in a future CR scenario using the Coase’s theorem and Schumpeter’s evolutionary theory. In fact, a market based spectrum mechanism to be deployed should enable low cost of transaction (Coase) and an innovative market structure which brings new entrants and services (Schumpeter).

According to the Coase theorem, transactions are valuable when the amount of players is higher and their offer is diversified. From this perspective, the Chilean market present an asymmetric assignment of spectrum, roaming demand for new operators, spectrum disparity (in amount and location) and different rate plans due to higher coexistence between prepaid and postpaid subscriptions. On the other side, Finnish mobile market has symmetric spectrum allocation, high operators’ cooperation, and high homogeneity of subscription plans (postpaid and flat rate). In addition, all Finnish mobile operators present similar traffic patterns (FICORA interview, 2011), while Chilean operators have bigger differences. Thus, the Chilean market presents a better scenario for spectrum usage improvements, due to the asymmetric regime of spectrum and different traffic patterns. Moreover, Chile presents regions with higher density of population (its

capital Santiago has 6 million inhabitants) as compared with Helsinki, the Finnish capital (about 1 million inhabitants in the metropolitan area).

On the contrary, Finland has higher availability of Wi-Fi internet access than Chile (46 versus 10 of fixed broadband internet connections each 100 inhabitants). Therefore, Finland has a better scenario than Chile of using the infrastructure accessing the non licensed band in a Cognitive Radio deployment. However, in both countries the absent of big WLAN operators make more difficult the cooperation with this kind of access.

3.2.2 Possible Cognitive Radio scenarios for Chile and Finland

This section presents possible Cognitive Radio scenarios from the following perspectives: spectrum sharing types, spectrum regimes, and industry cooperation scenarios.

Spectrum sharing scenarios can be classified according to the type of authorization they require (individual agreement between operators versus a general authorization given by the regulator) and the type of spectrum sharing (horizontal if sharing is done between equal parties, vertical if sharing is done between primary and secondary users). According to this classification, used among others by the FARAMIR project, the following scenarios are defined: Intra Operator Spectrum Management (cooperative spectrum sharing between incumbent operators), Hierarchical Spectrum Access on Licensed Bands (coordinated or opportunistic usage) and Spectrum Sharing on Unlicensed Bands (opportunistic use of free-license spectrum).

Spectrum regimes include a wide variety of types, ranging from exclusive usage to common usage. The ECC (report 132) defines a general category between individual and license exempt regimes a category called light-licensing, which includes both many individual authorizations coordinated by regulatory authority (limitation in the number of users) or a general authorization including a registration mechanism with technical requirements. On the other side, authorized shared access (ASA) allows the incumbent (spectrum owner) to share its licensed bands for secondary usage when spectrum is not needed. With ASA, the incumbent allows a limited number of others temporary users. ASA combines Command and Control with CR technologies (Forge, Horvitz and Blackman, 2012).

Considering industry scenarios, we may analyze different players in the industry such as mobile operators, local area operators (such as Wi-Fi operators), TV broadcasters and other operators (such as WiMAX operators).

Cooperation in spectrum usage presents more opportunities in Chile than in Finland, where the spectrum is organized symmetrically and operators have a similar customer base. The Chilean spectrum is asymmetric and more decentralized, and therefore is subject to further optimization. On the other hand, Finnish operators are already used to cooperate between themselves and

Cognitive Radio may be present an opportunity to share infrastructure further, which can minimize the cost of investments in new technologies.

In both countries, mobile users may get additional benefits through an opportunistic access to unlicensed bands, where local Wi-Fi networks give broadband coverage. From this perspective, Finland shows a better scenario because of its higher Wi-Fi penetration. Figure 7 (left) shows that even though the level of cooperation between industry players is different, opportunistic usage of the spectrum may enable new players in both cases. However, without any coordination or cooperation, the “tragedy of the commons” may be the result (decentralized and closed spectrum usage scenario). Cooperation brings openness to the industry, while an opportunistic usage brings innovation. Cognitive Radio scenario requires both cooperative and opportunistic usage.

Additionally, the phase diagram shows that light licensing may be a promising mean to decentralize the spectrum further (Figure 7, right). On the other side, ASA may help to increase the cooperation of incumbents. However, the spectrum regime alone may not be enough to increase the level of cooperation of the industry. In addition to this, Cognitive radio needs mechanisms enabling spectrum transaction, which solves several technical and economical aspects.

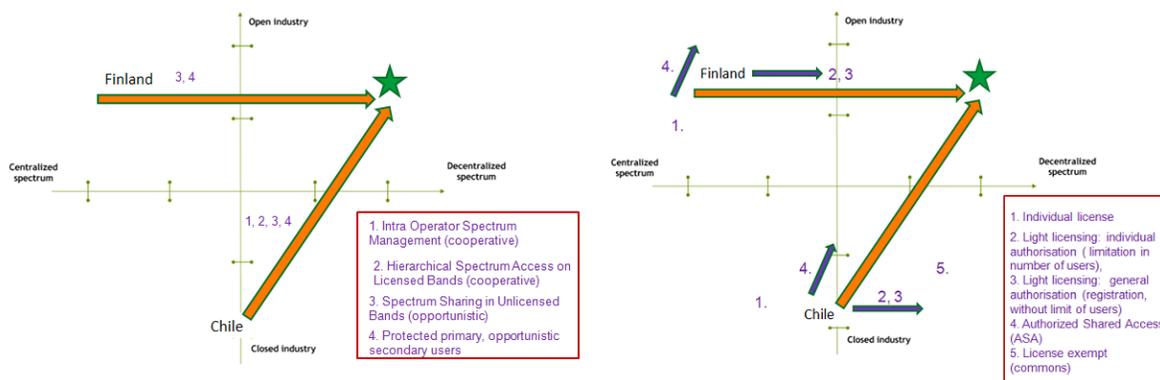


Figure 7: Possible scenarios to take advantage of the new Cognitive Radio technologies (left). Possible spectrum regimes to enable an introduction of a Cognitive Radio scenario (right)

Figure 8 analyzes from a general perspective different operators in the industry. Wide Area operators form currently cooperative or non cooperative oligopolies, while local area operators work independently without much cooperation. From a Coase theorem perspective, a Cognitive Radio scheme requires low transaction cost, symmetry of information (e.g. the existence of mechanism revealing price information between parties), initial low concentration of the tradable resource and well defined property right, which includes technical aspects such as interference (Crocioni, 2009). Figure 8 shows that these requirements demand more effort from mobile operators to join a tradable spectrum market. To achieve an open and decentralized scenario, the market needs the cooperation between different kinds of operators. We may divide operators into national or wide area operators such as mobile operators and local operators, such as WLAN or other local network operators (Markendahl, Casey, 2012). New service innovation may in this

scenario happen both locally and in the wide area, according to the Schumpeter's vision on creative destruction.

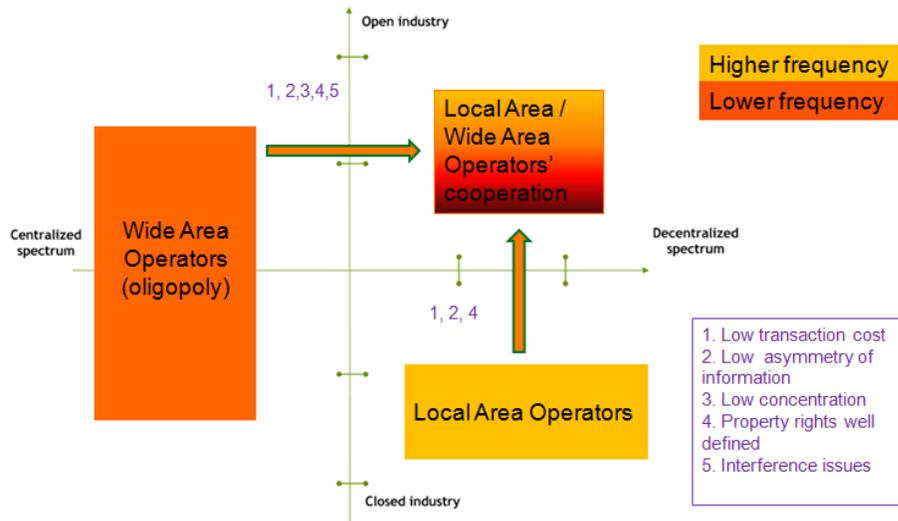


Figure 8: Possible cooperation between local and wide area operators.

4 Discussion and Conclusions

This paper develops a framework to analyze spectrum policy. This tool is useful to understand what kind of policy telecom regulators are practicing and where they are located. This framework uses scenario analysis done earlier in the field and applies it to spectrum regulation, taking into consideration relevant economic theories. The tool emphasizes that further regulation is needed to jump from an equilibrium of oligopoly to a scenario, where spectrum transactions enable new players to bring new services and innovation to the mobile market. Thus, this analysis suggests that the Coase theorem and Schumpeter's evolutionary ideas may be helpful to further analyze the path toward a regulation, which considers Cognitive Radio technologies.

In addition, a comparison between countries gives an overview of how they are performing in terms of industry structure and spectrum policy. For example, in the comparison presented in this paper, Finland shows to have high concentration of the spectrum, while Chile is lacking cooperation between existing players. Regulators should consider these issues in future spectrum policy decisions. Finally, this tool presents in a graphical way the main challenges of a future Cognitive Radio introduction.

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Appendixes

A. General Comparison between Finnish and Chilean spectrum regulation (Finnish data mostly taken from Shridar et al., 2012)

Factor	In Finland	In Chile
Spectrum Allocation per operator	2x11.3 MHz in 900; 2x24.8 MHz in 1800; 2x15 MHz in 2.1 GHz; 4.8 MHz unpaired in 2100 GHz; 2x20 MHz in 2600	3 incumbents: 1 x 60 MHz, 2 x 55 MHz at 850-1900 MHz, 2 new operators: 1x 30 MHz, 2 x 60MHz at 1.700 - 2100 MHz. Currently, 4G licitation at 2.6 GHz
Number of Primary Licensees	3 for 2G in 900 and 1800, 3 for UMTS in 2100; and 3 for LTE I 2600 with National License	4 primary licenses: Entel (60MHz GSM@ 1900MHz), Telefónica CTC (25MHz TDMA D-AMPS @ 800 MHz), Bellsouth (25MHz, TDMA D-AMPS @800MHz), Smartcom (30MHz, CDMA @ 1900MHz). For 3G: additional 30MHz for Telefónica @1900MHz. Claro bought Bellsouth & Smartcom, Entel continues with the same spectrum.
Distribution	Symmetric	asymmetric with spectrum cap (for 3G licensing)
Reselling	Allowed for LTE band	Not allowed yet
Regulator	Strong	Medium
Assignment method	Beauty contest and Auction	Beauty contest. If draw, auction is organized
Neutrality	harmonization of service and technology	Technology neutrality, harmonization of service
Type of dominant contract	Postpaid	Prepaid
Use of bandwidth intensive applications	High	Medium / High
Amount of wired telephone density	High	Relatevily high (21%)
Efficiency of Initial Spectrum Allocation	High	Medium / High
Availability of TV white space spectrum	Available	Available. In practiced may be licensed in 2015 or before

Number of potential secondary users	Moderate	Moderate
Coverage disparity	roll-out obligations determine; exists in rural areas	No disparity for incumbent operators. Disparity for new entrant operators (roaming agreements needed).
Revenue objective of the Policy maker	Low; Objective to promote newer technologies	Low; objective to promote coverage and high penetration of new technologies
Harmonization Policy of the Government	High; GSM, WCDMA and LTE adopted in different spectrum blocks as per EU directives	Harmonization of service, technologically neutral. In practice, after an initial technology diversity in 2G, all operators chose GSM based technologies
Technology policy of the policy maker	High technology orientation; intense promotion of newer technologies	Promotion of new services (technology neutral approach) while minimizing technological risk
National Infrastructure Policy	Medium/High; Allowing sharing of backhaul in rural areas	Law project for co-location of antennas. Cooperation between operators for sharing infra increasing
Green policy of the government	High; mandates energy efficient solutions	Moderate/low: Increasing in importance. Plan for infrastructure sharing policy
Policy directions on Spectrum Refarming	Started; operators are already deploying UMTS in 900 MHz	Operators offer 2G and 3G services within the same band
Policy Directions on Digital Dividend Spectrum	In progress	Not yet
Policy Directions on Secondary Market	None; MVNOs exist though sharing of spectrum not allowed	None, regulator supporting MVNO, but still few in the market

B. Comparison between countries in several competition indexes. (Source: The Global Information Technology Report 2010-2011)

Factor	Chile	Finland
Networked Readiness	4.3 (rank # 39 out of 139)	5.4 (rank #3 out of 139)
Laws relating to ICT	5.0 (rank # 29)	5.5 (rank #7)
Intellectual property protection	3.7 (rank # 58)	6.2 (rank # 2)
Internet & telephony competition	6 (rank # 1)	6 (rank #1)
Mobile network coverage	100% (rank # 1)	99.5% (rank # 43)
Internet bandwidth, Mb/s per 10,000 pop	40.8 (rank # 48)	172.2 (rank # 18)
Mobile cellular tariffs (PPP \$)	0.31 (rank # 53)	0.17 (rank # 21)
Fixed broadband internet tariffs	68.9 (rank # 100)	29.1 (rank # 43)
Impact of ICT on access to basic services	5.0 (rank # 33)	5.3 (rank # 25)
Firm level technology adoption	5.3 (rank # 37)	6.0 (rank # 12)
Government success in ICT promotion	4.5 (rank # 55)	5.2 (rank # 23)

C. Main ideas taken from interviews to the National Regulatory Authority

Issue	FICORA 	SUBTEL 
Level of competition	Prices are the lowest in Europe. No need for more operators. Additional spectrum will probably go to incumbent operators	There is place for more competition. Subtel wanted to allocate additional spectrum to new operators through spectrum cup.
Level of cooperation between operators	Operators cooperate very much	In the past, infrastructure competition. Now, operators are beginning to cooperate. New laws will help cooperation.
Licensing mechanism	Auction gave good results and will continue in the future. We enabled reselling in the last auction	Not planned to change the licensing mechanism. Reselling the whole license "has been allowed" always.
Digital dividend	To mobile broadband	Available but not yet planned. Probably to mobile broadband services
Vertical competition	NO and SO are separated. MVNO consolidated same years ago.	New law about NOs. However, it is not easy in Chile to give obligations to operators. NO are just allowed from now on.
Horizontal competition	Future interaction with WiFi may increase.	WiFi penetration in Chile is still low. Wi-Max did not prosper. New operators drive horizontal competition.