# *A Revised Perspective on Property Rights and Wireless License Values*

## Introduction and Background

The world around us is filled with a type of energy known as electromagnetic radiation. It is emitted by the sun in the form of UV radiation, and also artificially over transmitters such as those used in telecommunication services such as radio, cellular services, satellite TV or telephony. Transmitters broadcast at a specific frequency, which measures the amount of energy that is released during transmission. When two transmitters emit a broadcast at the same frequency, receivers begin to accept both signals which can scramble the broadcasts, which is called interference. Interference can hamper communications and is major issue for communication technologies that rely on stable, unadulterated airwaves (Hazlett, 2008).

Governments around the world subscribe to a set of policies laid out by a UN organization called the International Telecommunications Union (ITU). The ITU and other organizations, like the World Bank and International Development Fund, have harmonized the way in which governments should organize their spectrum holdings which is by the establishment of an independent, national regulatory body with the responsibility of spectrum allocation, herein called "regulator". Some examples of this type of regulator include those to the likes of the Federal Communication Commission (United States), Superintendencia de Telecomunicaciones (Guatemala), and the Federal Telecommunications Institute (Mexico). These organizations are tasked with dividing and organizing spectrum licenses along geographic demarcations such as municipalities, regions, states or provinces, or an entire nation (Hazlett, 2008)

The rights to use spectrum for the purposes of broadcasting (herein referred to as "spectrum") are typically obtained by means of spectrum auctions, namely, first-price sealed-bid auctions. Spectrum can also be obtained by direct purchasing, or by transferring a license to a third party, depending on local regulations. Spectrum auctions are big business. For example, Auction 97, which organized the AWS-3 spectrum in the United States, raised over $44 billion and saw the issuance of some 1,614 spectrum licenses.[1]

The ways by which regulators organize spectrum falls into two major categories, liberalized markets and non-liberalized markets, however some markets, like the United States, are semi-liberalized. A non-liberalized spectrum market is one where regulators sell access by means of a spectrum license, but their access is contingent upon adhering to a set of regulations set forth by the government, which could include stipulations such as restrictions on the type of transmissions used in the allocated block, or band, of frequency, intercarrier connectivity guidelines, contractual time obligations that added to licenses, or development commitments that must be followed or the licensee risks their access being revoked (Hazlett, 2008).

Liberalized markets see the benefit of explosive innovation and rapid influx of foreign direct investment. This is an option that regulators keep in their toolbox to deal with high market concentration, poor services, high prices, and lack of coverage. A liberalized spectrum market is a relatively new spectrum policy management system, which prioritizes innovation and development over stringent regulations. In a liberalized spectrum system, regulations are absent, and license-holders are free to broadcast however they see fit, so long as they remain within the width of their spectrum's bin. A few examples of countries that have liberalized their spectrum market to this extent are: Guatemala, El Salvador, Australia, and New Zealand, amongst others. The United States is a semi or quasi-liberalized spectrum market because the FCC allows spectrum holders and other third-parties to exchange and sell licenses within the terms of their agreement with the government (Hazlett, 2008).

A study conducted by Hazlett in 2008 analyzed the connection between liberalization policies, such as those discussed earlier, and the pricing of 3G spectrum auctions, and further to be able to econometrically define this relationship. Previous investigations into this topic had a treasure trove of data at their fingertips, as by 2008 most countries in the world had seen their spectrum market diversified to a point that nearly all had a functioning national mobile data supporting carrier, or several. More so, 3G technologies are versatile and can operate over a wide range of frequencies. The major 3G technologies that were deployed globally are: EV-DO, EDGE, W-CDMA, and HSPDA (Coldewey, 2010). This study will instead focus on the development of 4G networks across the Americas to see how spectrum auction prices for mobile licenses have changed since the advancement of a new mobile technology generation.

## Methodology

For the purpose of this study, two major technologies that are labeled as 4G by major worldwide carriers were identified for investigation, which are LTE, which typically operates in the 700-800MHz PCS range, and the AWS spectrum, which has various bands through 1695-2200MHz, and a 3.75G technology known as HSPA+, which provide peak data transmission rates similar to that of LTE (~50-75 mb/s). HSPA+ is part of the UMTS family of technologies and typically operates in the 1800-1900MHz range. Furthermore, both LTE and HSPA+ enjoy wide adoption across the globe (Coldewey, 2010). These spectrums were previously used by wide band transmission technologies, such as that of AM/FM radio and TV broadcasting. Regulators were tasked with a mission branded as “re-farming,” or repurposing this spectrum into bands that could be organized and sold for transmissions with more efficient technologies, which in this case is mobile telephony and mobile broadband (Hazlett, 2008).

The data used in the regressions was collected through the direct regulators which conducted the sales, reporting by other firms, and publications by mobile technology organizations, like the ITU, Organization for American States, and GSMA Intelligence, as well as other scholarly economic journal articles, which is tabulated in the reference section at the end of this document. Data on 22 independent spectrum auctions, *j*, in 17 different countries, *i*, in North and South America were chosen to be inspected for this analysis. Although 22 observations are an outstandingly low number to be used for regressional analysis, Hazlett in his investigation used only 38 auctions in 24 countries to establish his findings, and further this low number of observations is highly supported by literature research.[7, 16]

**TABLE 1**

**Key Statistics for Data Set**

| Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| AVG_P($e^9$) | 3.655 | 10.588 | 0.00531 | 44.899 |
| LIC_VAL | 13.077 | 3.834 | 10.000 | 20.000 |
| LEGAL | 5.379 | 1.292 | 3.730 | 7.850 |
| LIB | 0.000 | 0.200 | 0.000 | 1.000 |
| NASDAQ($e^3$) | 3.557 | 1.234 | 0.216 | 5.021 |
| HHI3 | 3923 | 1288 | 2353 | 5545 |
| GNIPC ($e^3$) | 20.623 | 13.671 | 4.780 | 53.741 |
| DENSE | 97.944 | 149.321 | 3.940 | 656.998 |
| URBAN | 70.862 | 18.595 | 28.002 | 91.377 |
| AUCT | 0.619 | 0.498 | 0.000 | 1.000 |
| THRT | 0.238 | 0.436 | 0.000 | 1.00 |
| MP | 109.697 | 33.358 | 1.001 | 171.509 |

The number of licenses issued in a given auction is a control variable. The *average* price per license for that auction is the total price rise by the auction divided by the total number of bands awarded by said auction, bearing in mind that in an auction each different license could fetch a different price, but this data was not included in the regression analysis. License validity, LIC_VAL, indicates the time in years that each license issued is legally valid, at point which the lease terminates and carriers must renew or relinquish their rights to regulators for reorganization. Together, these three variables, total amount raised (in USD), number of licenses, license validity, are data that are unique to each auction (Hazlett, 2008).

The remainder of the data collected describes the mobile phone market in the country at the time of each given auction. Legal, LEGAL, is a generic score indicating the integrity of property rights and rule of law in each given country for the appropriate year.[6] Liberalization, LIB, is a dummy variable to describe the type of national spectrum regime, with 1 for a liberalized spectrum policy, and 0 for otherwise. LIB is the most important explanatory variable because due to its nature as the primary treatment variable. This study focuses on the extent to which a liberalized market for mobile spectrum licenses affects the price that was collected via auction (Hazlett, 2008). All other explanatory variables are controls.

NASDAQ refers to the average NASDAQ index composite closing price by year.[11] The Herfindahl Hirschman Index, HHI3, is a measurement of the extent to which the mobile phone industry is centralized in each country for the appropriate year.[10, 12] GNIPC is the conventional measurement of gross national income per capita for each country during the appropriate year. Population Density, DENSE, is given for each country, during the appropriate year. Urbanization Rate, URBAN, is similar: the percentage of the population living in urban population centers for each particular country, during the appropriate year.[16] Auction, AUCT, is categorical data regarding the type of sale by which the spectrum was licensed, with 1 referring to a typical first-price sealed-bid auction, and 0 for otherwise. Total population and country square mileage are both nominal, absolute measurements of each country, for the appropriate year in which the auction was conducted.

In addition to the above, which were suggested in the model used by Hazlett, two new variables were added. These variables were hypothesized to be valuable in measuring the effect of government policies in manipulating spectrum pricing. The first new addition, throttling (THRT), is a dummy variable that indicates whether or not the particular country, at the time of the auction, had any regulations regarding the protection of mobile internet users. This is most typically useful in the regulation the throttling of mobile broadband referring to the practice of mobile carriers drastically raising prices for data downloads. The throttling dummy is such that a 1 represents that no law exists in the country guarantees rights for internet users and further lacks a law to regulate throttling, and 0 to represent that a law has been enacted to regulate throttling or protect internet user rights.[14] The second, mobile penetration, MP, refers to how many mobile phone subscriptions there are per 100 people in the given country and year.[15]

The total amount raised was regressed on all explanatory variables, continually dropping variables that were found insignificant until a final regression was constructed, which is shown below. We used the natural log of all variables involved (explanatory and response), excluding categorical data. Looking below, Total Amount Raised as the response variable (represented as P for "Price"), was regressed on our treatment variable of the liberalization of the spectrum regime (represented as LIB), along with a series of control variables. The final proposed model **(3)** is indicated below:

**TABLE 2**

**Estimators**

| | **(1)** | **(2)** | **(3)** |
|---|---|---|---|
| *Intercept* | 48.746* | 44.530* | 41.361** |
| | (18.052) | (15.902) | (12.331) |
| $LIC\_VAL_{ij}$ | 2.644 | 4.032` | 4.064` |
| | (2.342) | (2.016) | (1.945) |
| $NASDAQ_{ij}$ | 1.948 | 2.379` | 2.720*** |
| | (1.948) | (1.125) | (0.5624) |
| $HHI3_{ij}$ | -3.598 | -5.453** | -5.504** |
| | (2.287) | (1.658) | (1.598) |
| $GNIPC_{ij}$ | 0.607 | -0.270 | -0.203 |
| | (0.815) | (0.739) | (0.688) |
| $DENSE_{ij}$ | -0.558 | -0.273* | -0.692* |
| | (0.319) | (0.273) | (0.254) |
| $LEGAL_{ij}$ | -3.824` | -4.162* | -4.185* |
| | (2.064) | (1.845) | (1.784) |
| $LIB_{ij}$ | -12.957 | -1.163 | |
| | (9.976) | (3.492) | |
| $AUCT_{ij}$ | 1.100 | | |
| | (0.930) | | |
| $THRT_{ij}$ | -0.4996 | | |
| | (0.865) | | |
| $MP_{ij}$ | -2.309 | | |
| | (1.958) | | |

**Residuals**

| | **(1)** | **(2)** | **(3)** |
|---|---|---|---|
| Min | -1.4397 | -1.5351 | -1.448 |
| 1Q | -0.6768 | -0.8941 | -0.8462 |
| Med | 0.0000 | -0.1544 | -0.1516 |
| 3Q | 0.4501 | 0.7183 | 0.8312 |
| Max | 1.7610 | 1.9628 | 1.9154 |

| | **(1)** | **(2)** | **(3)** |
|---|---|---|---|
| Residual SE: | 1.312 | 1.26 | 1.22 |
| *(on 10, 13, and 14 DF, respectively.)* | | | |
| Multiple $R^2$: | 0.8377 | 0.8052 | 0.8036 |
| Adjusted $R^2$: | 0.6753 | 0.7004 | 0.7194 |
| F-statistic: | 5.16 | 7.679 | 9.546 |
| p-value ($e^{-3}$): | 7.978 | 0.0886 | 0.279 |
| AIC [1]: | 79.423 | 77.246 | 75.425 |
| BIC [1]: | 91.957 | 86.647 | 83.781 |

*Note: Significance codes:* “ ` ” p<.1“ * ” p < .05 “ ** ” p < .01“ *** ” p < .001

All regressions were ran are shown above, and the conclusions and interpretations are focused on model **(3)**, which showed significance for three variables, $HHI3_{ij}$ $DENSE_{ij}$, and $LEGAL_{ij}$,. The AIC is 79.423 and $R^2$ is 0.6753. Most importantly, the VIF test for multicollinearity resulted negative. However, the Breush-Pagan test for homoskedasticity has a p-value < 0.5, this might be due to a sample size less than 30, which by itself violates the sixth MLR assumption.

## Interpretations and Conclusions

The conclusions that can be drawn from an investigation on the macroeconomic forces that affect spectrum licensing prices are only slightly conclusive at best. The actual conclusions, however, that can be taken away from this regression are severally weakened due to the extremely small sample size and understanding the quality of the data provided. This regression could naturally be improved by increasing the number of auctions that are conducted. This is a painstakingly slow process as regulators in the Americas struggle to pass meaningful spectrum reform necessary to be able to re-farm spectrum from TV and radio broadcasters (Hazlett, 2008).

The reproducibility of this study is limited, due to the inaccessibility of data and the lengths to which a researcher must use to attain such data. Studies regarding the macroeconomic impact of spectrum licensing nearly always included highly developed nations and include a wide geographical range. This topic is poorly studied, and in nearly every academic article that was revised during the literature review discussed the need for regulators to be more effective in their efforts to repurpose spectrum as fast as possible.

A 2017 study also called into question the validity of Hazlett's results. The authors find that even in mobile telephony, a market that is highly susceptible to change, this type of study could be under-shadowed by incomplete conclusions regarding data, adding that "the identity of the owners of particular spectrum bands is likely to be more dispersed than Hazlett suggests," indicating the complex nature of spectrum auctions and questions the mechanisms that Hazlett proposed in his 2008 article (Weiser, Hatfield, 2007).

When approaching these results with an open mind however, there are some observable differences between the time when Hazlett first investigated this relationship in the early 2000s. For one, spectrum prices are rising astronomically, and the available real estate for firms to enter the market is become more tightly controlled by major market movers, i.e. multi-national telecommunication corporations like AT&T, Telefónica, and Telmex. Moreover, increased international cooperation on telecommunications standards has forced carriers put up to tens of millions of dollars for a single band of frequency. A further conclusion seems to be that because of the rapid innovation and technological evolution that is constantly occurring in the mobile phone industry, other market factors such as market penetration, population factors, and market concentration are significantly more influential in determining spectrum prices than market liberalization. However, for emphasis, these conclusions are unable to be validated due to the low number of observations.

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Supplement 1.

| Country | AUCT_YR | AVG_P | LIC | LIC_VAL | Legal | LIB | NASDAQ | HHI | GNIPC | DENSE | AUCT | URBAN | total_pop | cnty_sq_mile | MP | THRT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guatemala | 1998 | 28150000 | 784 | | 3.94 | 1 | 215.632292 | 3600 | 5855 | 103.8960526 | 0 | 44.659 | 11133501 | 42043 | 1.000987919 | 0 |
| Antigua and I | 2007 | 5310000 | 6 | 10 | | 0 | 2587.587504 | | 23421 | 207.6840909 | 0 | 28.002 | 91381 | 170 | 122.9807071 | 1 |
| Trinidad and | 2007 | 5310000 | 6 | 10 | 4.28 | 0 | 2587.587504 | | 29658 | 255.2163743 | 0 | 54.59 | 1309260 | 1981 | 115.3170493 | 0 |
| United States | 2008 | 19120378000 | 1090 | 10 | 7.41 | 0 | 2148.948334 | 2353 | 51095 | 33.24368685 | 1 | 80.438 | 304093966 | 3797000 | 86.13129085 | 0 |
| Panama | 2008 | 22570526 | 5 | | 5.18 | 0 | 2148.948334 | | 14170 | 47.29981168 | 0 | 64.56 | 3516268 | 3516268 | 111.347 | 0 |
| Brazil | 2012 | 508000000 | 23 | 10 | 5.12 | 0 | 2984.228353 | 2534 | 14797 | 23.995887 | 1 | 82.532 | 200560983 | 3288000 | 123.8145622 | 0 |
| Chile | 2012 | 12225294 | 6 | 20 | 6.73 | 0 | 2984.228353 | 5545 | 20335 | 23.28043178 | 1 | 84.923 | 17309746 | 291933 | 138.3092103 | 1 |
| Bahamas, The | 2012 | 62500000 | 1 | 15 | 6.48 | 0 | 2984.228353 | | 28845 | 37.16673327 | 0 | 87.189 | 372039 | 5358 | 80.63670744 | 0 |
| Barbados | 2013 | 25000000 | 1 | 15 | 6.02 | 0 | 3575.141642 | | 15352 | 656.9976744 | 1 | 31.429 | 282509 | 166 | 108.9197158 | 0 |
| Brazil | 2013 | 2176752849 | 4 | 10 | 4.62 | 0 | 3575.141642 | 2534 | 15244 | 24.21694683 | 1 | 85.209 | 202408632 | 3288000 | 133.9368763 | 0 |
| Colombia | 2013 | 462000000 | 9 | | 3.86 | 0 | 3575.141642 | 4306 | 11847 | 42.67055521 | 1 | 79.061 | 47342981 | 440800 | 106.2356297 | 0 |
| Jamaica | 2013 | 25000000 | 1 | 20 | 4.76 | 0 | 3575.141642 | | 7834 | 263.3247461 | 0 | 54.35 | 2851807 | 4244 | 99.80324755 | 0 |
| Peru | 2013 | 257000000 | 2 | | 4.7 | 0 | 3575.141642 | | 10910 | 23.87946563 | 1 | 76.989 | 30565716 | 496200 | 97.47292359 | 1 |
| Argentina | 2014 | 2233000000 | 4 | 15 | 3.73 | 0 | 4414.850057 | 5246 | 18429 | 15.7056572 | 1 | 91.377 | 42981515 | 1074000 | 142.4663975 | 0 |
| Chile | 2014 | 20623000 | 7 | | 6.58 | 0 | 4414.850057 | 5545 | 21507 | 23.68936105 | 1 | 87.303 | 17613798 | 291933 | 134.4441329 | 1 |
| Nicaragua | 2014 | | 7 | | 4.3 | 0 | 4414.850057 | 4950 | 4780 | 49.9750457 | 0 | 57.7 | 6013997 | 50338 | 117.5235039 | 0 |
| Canada | 2015 | 2109147421 | 39 | 10 | 7.85 | 0 | 4935.745809 | 2921 | 42512 | 3.940449068 | 1 | 81.259 | 35832513 | 3855 | 82.79621957 | 0 |
| United States | 2015 | 44899451600 | 1611 | 10 | 7.23 | 0 | 4935.745809 | 2637 | 53741 | 35.09621718 | 1 | 81.671 | 321039839 | 3797000 | 119.4973905 | 0 |
| Costa Rica | 2016 | 43000000 | 6 | | 5.89 | 0 | 5021.041707 | | 14490 | 95.12875049 | 1 | 77.735 | 4807852 | 19730 | 171.5090398 | 0 |
| Mexico | 2016 | 173010000 | 11 | 15 | 4.13 | 0 | 5021.041707 | 4900 | 16623 | 65.60890095 | 0 | 79.577 | 125890949 | 761600 | 88.51342699 | 0 |
| Peru | 2016 | 911200000 | 6 | | 4.77 | 0 | 5021.041707 | | 11635 | 24.82331172 | 1 | 77.539 | 31376671 | 496200 | 120.9849191 | 1 |

For detailed source data, please visit: https://www.goo.gl/T8gKn2