The Potential Economic Value of Unlicensed Spectrum in the 5.9 GHz Frequency Band: Insights for Future Spectrum Allocation Policy

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Agenda

- Motivation
- Our Approach
- Assumptions and Limitations
- Trade-off with DSRC
- Detailed Methods
- Allocation Alternatives
- Conclusion

Motivation

- Large increase in WiFi data traffic and forecasted demand
- Reports of looming unlicensed spectrum crunch
- Questions about approach to unlicensed spectrum allocation
- Specific questions about 5.9 GHz band facilitated study
- Intended contribution to the general discourse

Our Approach

- Started by asking about value if band reallocated for open use
- Next asked what about this band creates value
- The 5.9 GHz band could create potential value in two ways
- Consumption-focused across all people, devices, applications
- Emphasis on residential consumption excludes enterprises
- Focus on measuring direct value, not intangible value of information

Assumptions and Limitations

- Because of the nature of spectrum, there are many assumptions
- Spectrum not homogeneous good
- Marginal value is not constant and changing over time
- Lots of proxies and imperfect data, using best data available

The Trade-off with DSRC

- Potential value of DSRC similarly a difficult question
- Currently evidence that market value is small but did not study
- Some auto manufacturers are using cellular networks, and device manufacturers are designing products for both
- Much of the potential value likely stems from reduced fatalities and accidents
- We do not subtract out the potential value of DSRC from our estimates

Contribution to GDP – Approach 1

- Focus on benefit of 160 MHz channel
- First estimated a new elasticity for returns to speed:

$$\ln\_GDP_{it} = \beta_0 + \beta_1 \times \ln\_speed_{it} + \beta_2 \times \ln\_population_{it} + \beta_3 \times unemployment\_rate_{it} + \delta \times State_i + \varphi \times Time_t + \Psi \times (State \times Time)_{it} + u_{it}.$$

- Second, converted to estimate appropriate for large changes in speed
- Third, applied Katz (2018) methodology for estimating GDP contribution from speed differential between cellular and WiFi networks
- Estimated a range, given differential between 80 MHz channel data rate, 160 MHz channel data rate, and status quo

Approach 1 - Estimates

Table 5.3. Range of Total Additional Contribution to GDP from 5.9 GHz

	2017 C	2017 D
Difference from B	$38.0 billion	$59.8 billion
Difference from A	$75.1 billion	$96.8 billion

Scenario A = 20 MHz channel; Scenario B = 40 MHz channel;
Scenario C = 80 MHz channel; Scenario D = 160 MHz channel

Contribution to GDP – Approach 2

- Focus on additional 75 MHz of data capacity
- First, used Nyquist Theorem which relates data capacity, bandwidth, and modulation scheme (QAM): $C_t = 2 * B_t * log_2 M$
- Second, estimated how many devices could stream data on 75 MHz, using both load share (data traffic allocation) and device share (device allocation)
- Third, monetized in terms of residential internet revenues, taking the estimated share that is WiFi, and in terms of device revenues, using averages prices
- Scaled to number of internet-enabled households in the United States

Approach 2 - Estimates

- Using device traffic load share: $105.8bn
- Using total device share: $71bn

Consumer Surplus (CS) & Producer Surplus (PS)

- CS estimated over three channel sizes using:
  - WTP for an additional Mbps from the literature (Nevo 2016)
  - Residential WiFi share of total WiFi consumption
  - Number of Internet-enabled households

➢ Estimate CS range between $65bn and $172 billion

- PS estimated using per-MHz revenue from the FCC 2016 Incentive Auction

➢ Estimate PS to be about $18bn

Allocation Alternatives

- All affect realization of potential economic value:
  - Status Quo
  - Partial Sharing
    - Co-channel
    - Adjacent
  - Full Reallocation

Conclusion

- All together, we estimate the potential economic value of the 5.9 GHz frequency band as:

Table 10.1. Summary of Economic Value of 5.9 GHz Band ($ billions)

	Lower Estimate	Upper Estimate
Contribution to GDP		
Approach 1	$59.8	$96.8
Approach 2	$71.0	$105.8
Consumer surplus	$64.6	$172.2
Producer surplus	$17.7	
Total potential economic surplus	$82.3	$189.9

Questions?

Thank You!

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Backup Slides

Approach 1 – Regression Model Specifications

The specifications for our seven models are as follows:

1. Model specification detailed above.
2. Same specification as Model 1, except the dependent variable is the natural log of per capita real GDP, so that population is not included.
3. Same model specification as Model 1, except adding another predictor for the natural log of the number of unique IP address counts (ln_ipcount).
4. Same specification as Model 1, except using the natural log of a one quarter lag of average speed (ln_speed1) instead of the natural log of average speed.
5. Same specification as Model 1, except variation outlier states (Delaware, Ohio, Kansas) removed.
6. Same specification as Model 1, except temporal trend outlier state (Washington, D.C.) removed.
7. A two-stage least squares IV approach using one quarter, two quarter, and one year lags of speed as instruments for average speed (ln_speed_IV).

Approach 1 – Regression Analysis

Table 5.1. Model Specifications for Elasticity of Speed: Coefficients and Standard Errors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln_speed	**0.0197****	**0.0193****	**0.0171***		**0.023***	**0.0207****	
	(0.0092)	(0.0095)	(0.0087)		(.0134)	(.0095)	
ln_speed1				**0.0198****			
				(0.0084)			
ln_speed_IV							**0.0222****
							–0.0102
ln_population	3.027**		3.035**	3.129**	3.041**	3.164**	3.362**
	(1.065)		(1.077)	(1.161)	(1.073)	(1.085)	(1.192)
unemployment_rate	–0.0084*	–0.0084*	–0.0085*	–0.0079*	–0.0079	–0.0081*	–0.0068*
	(0.0044)	(0.0044)	(0.0044)	(0.0044)	(.0048)	(.0043)	(0.0039)
ln_ipcount			–0.0039				
			(0.0077)				
N	1,450	1,450	1,450	1,400	1,363	1,421	1,250
R^2	0.9998	0.9961	0.9998	0.9998	0.9998	0.9998	0.9998
AIC	–7980.63	–7841.27	–7980.19	–7787.75	–7471.17	–7812.53	
BIC	–7822.25	–7688.17	–7816.53	–7635.66	–7314.65	–7654.76	

DTE: Bolded values are the values on the coefficient of interest (β_1) for each model specification. For simplicity, xed, Time, and Interaction Fixed × Time Effect coefficients are not reported here.
Denotes statistical significance at the 0.05 significance level; *Denotes statistical significance at the 0.10 gnificance level.

Approach 1 – Contribution Calculation

Table 5.2. Estimation of Speed Differential for Total U.S. Traffic (in Mbps)

Scenario Description Relative to A		**Increase 5 GHz Weight; Channel Bandwidth Stays 40 MHz**	**Increase 5 GHz Weight and Channel Bandwidth to 80 MHz**	**Increase 5 GHz Weight and Channel Bandwidth to 160 MHz**
	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**
Average speed of 2.4 GHz	173	173	173	173
Average speed 5.0 GHz	360	360	780	1560
Average speed of weighted average	211	267	477	867
2.4 WiFi weight	0.8	0.5	0.5	0.5
Speed decrease (average speed of 2.4 GHz/average weighted average speed)	–17.73%	–35.01%	–63.64%	–80.00%
Model coefficient	1.37%	1.37%	1.37%	1.37%
Decrease in real GDP per capita	–0.24%	–0.48%	–0.87%	–1.10%
GDP per capita (current prices)	59,483	59,483	59,483	59,483
5 GHz traffic (% Total WiFi Traffic)	20.00%	50.00%	50.00%	50.00%
Per capita GDP reduction (current prices)	–29	–143	–259	–326
Population	325,983,000	325,983,000	325,983,000	325,983,000
Total contribution	**$9.4 billion**	**$46.5 billion**	**$84.5 billion**	**$106.3 billion**

Approach 2 – Data Traffic Load Share

Table 6.3. Economic Value of 75 MHz Using 2017 Device Traffic Load Share

Device	Average Price, $[a]	Device Traffic/ Month (GB)[b]	Devices per 75 MHz (Noiseless)	Device Traffic Load Share, 2017	Added Devices (Load Share)	Data Revenue, $ (Load Share)	Device Revenue, $ (Load Share)
4G smartphone	363	8.73	1.4	17.8%	21,905,852	12,159,432	7,951,824,146
Tablet	247	10.31	1.4	14.0%	17,227,322	11,292,067	4,255,148,529
Smart home devices	75	1.70	3.0	0.1%	245,810	26,579	18,435,730
Laptop	750	43.49	2.0	66.5%	118,219,368	326,981,498	88,664,526,168
Gaming console	300	1.17	3.0	0.3%	681,398	50,794	204,419,259
Virtual reality system	405	18.00	0.2	0.3%	61,506	70,417	24,910,086
5G smartphone	363	8.73	1.5	1.0%	1,373,490	762,393	498,576,850
Monthly total						$351.3 million	
Annual total						$4.2 billion	$101.6 billion
Total annual revenue						**$105.8 billion**	

[a] We used publicly available data elicited from a simple web search for average prices, searching for "average price [X device] United States 2018."
[b] We derive these values using Katz (2018). For example, Katz reports that 62 percent of total smartphone traffic (14.06 GB/month) was fixed wireless traffic (WiFi).

Approach 2 – Device Share

Table 6.4. Economic Value of 75 MHz Using 2017 Total Device Share

Device	Average Price, $	Device Traffic/ Month (GB)	Devices per 75 MHz (Noiseless)	Share of Total Devices, 2017	Added Devices (Device Share)	Data Revenue, $ (Device Share)	Device Revenue, $ (Device Share)
4G smartphone	363	8.73	1.4	41.7%	51,346,293	28,501,140	18,638,704,178
Tablet	247	10.31	1.4	20.9%	25,737,930	16,870,551	6,357,268,749
Smart home devices	75	1.70	3.0	1.1%	2,957,804	319,817	221,835,316
Laptop	750	43.49	2.0	29.0%	51,619,170	142,772,829	38,714,377,751
Gaming console	300	1.17	3.0	4.5%	11,893,022	886,549	3,567,906,516
Virtual reality system	405	18.00	0.2	0.4%	69,898	80,024	28,308,835
5G smartphone	363	8.73	1.5	2.4%	3,219,396	1,787,012	1,168,640,836
Monthly total						$191.2 million	
Annual total						$2.3 billion	$68.7 billion
Total annual revenue						**$71.0 billion**	

Consumer Surplus Calculation

Table 7.1. Estimates of Consumer Surplus from Opening Up the 5.9 GHz Frequency Band (in $)

Option	Bandwidth, MHz	Capacity, Mbps	Willingness to Pay per Mbps	Number of Households	Penetration Rate	Residential WiFi Share	Change in Consumer Surplus per Household per Year	Total Change in Consumer Surplus per Year
1	60	960	1.76	125,170,072	0.71	0.43	726.53	**$64.6 billion**
2	80	1280	1.76	125,170,072	0.71	0.43	968.70	**$86.1 billion**
3	160	2560	1.76	125,170,072	0.71	0.43	1,937.41	**$172.2 billion**

Other Policy Impacts

Table 8.1. Potential Effects of Trends and Policies on WiFi Demand and Value

Trend or Policy	Impact on Demand
5G	Unclear or demand-neutral
Opening of the 6 GHz	Unclear or demand-neutral
New entrants into the wireless communications provider market	Increase
Trade policy	Decrease
Internet regulation	Unclear or demand-neutral
Privacy and cybersecurity concerns	Unclear or demand-neutral
Rise of digital natives as today's youth enter adulthood	Increase
Rise of online and internet-enabled work	Increase
Digitization of industry (M2M)	Increase
V2V/V2X evolution	Increase