

The Broadcasters' Transition Date Roulette: Strategic Aspects of the DTV Transition

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Abstract: Broadcast television's analog to digital “DTV transition” in the U.S. represents an unprecedented technological event touching directly or indirectly nearly every American household. On June 12, 2009, the last full-power TV stations around the nation will cease over the air transmission of analog television and today transmit only digital television (DTV). The date was the culmination of more than ten years of complex regulatory decisions that have provided broadcast station managers now two mandatory cutoff dates and years of varying regulatory conditions for voluntary transitioning in advance of a mandatory cutoff date. Consumer's demand for the new DTV services also reflects the changing face of media delivery and consumption. Stations around the nation have transitioned individually, in groups, and together with an entire market in markets around the nation. Facing potentially dramatic changes in their costs, revenue, and other engineering concerns, firms acted in response to both market and regulatory forces. This paper will identify and describe the various forces that influenced the DTV transition. In particular, we focus on the strategic aspects of the decisions, using a model from game theory. In the paper, we examine both theory and data to explore the decision making process of broadcast station managers and markets facing a diverse set of opportunities for when to make the switch to all Digital TV broadcasting.

[▪] The opinions expressed are those of the author and do not necessarily represent the views of the Federal Communications Commission or the United States Government.

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Strategic Aspects of the DTV Transition

Furthermore, we expect that many stations will transition early and begin operating their final post-transition facilities in advance of the deadline and the onset of the winter months.¹

Introduction

Broadcast television's analog to digital "DTV transition" in the U.S. represents an unprecedented technological event touching directly or indirectly nearly every American household. Consumers' demand for the new DTV services, which have a sharper picture, smoother motion, better sound, and multiple sub-channels providing more viewing options, reflects the changing face of media delivery and consumption. On June 12, 2009, the last full-power TV stations in the U.S. ceased over the air transmission of analog television. Today, all full-power stations transmit only digital television (DTV). The date was the culmination of more than ten years of complex regulatory decisions that have provided broadcast station managers now two mandatory cutoff dates and years of varying regulatory conditions for voluntary transitioning in advance of a mandatory cutoff date. Stations around the nation have transitioned individually and in varying degrees of coordination with each other in the local markets and around the nation. Facing potentially dramatic changes in their costs and revenue, as well as other engineering concerns, firms acted in response to both market and regulatory forces. In this paper, we identify and describe the various forces that influenced the DTV transition. In particular, we focus on the strategic aspects of the decisions, modeling the stations' decisions with tools from game theory. We focus on the stations' decision whether to transition on February 17, 2009, the planned transition date until Congress delayed mandatory transition, or whether to continue to broadcast in analog until a later date. In the paper, we examine both theory and data to explore the decision making process of broadcast station managers facing a choice of when to switch to all digital TV broadcasting.

The inherent trade off between switching earlier or later depends on the costs and benefits of switching to DTV. Broadcasting in DTV requires much less power than in analog, and stations could realize savings estimated at several thousand dollars per month at the low end, to \$22 million for the

¹ *Third Periodic Review of the Commission's Rules and Policies Affecting the Conversion To Digital Television*, MB Docket No. 07-91, *Report and Order*, FCC 07-228, 23 FCC Rcd. 2994, 3017 para. 41 (rel. December 31, 2007) (*Third Review Report and Order*)

February to June period for the PBS network.² Balancing the cost savings are fears that technical problems or changing broadcast footprints would cost a station switching to DTV viewership, and therefore ad revenue. These fears are heightened if other stations in the local market do not switch to DTV early, because then they might gain the lost analog viewers at least temporarily, and perhaps permanently due to habit-formation. Thus each station must consider not only its own costs and revenues, but also the decisions made by the other stations. Our game theoretic model isolates the factors that drive stations in a market toward coordinating their actions or not.

The model predicts that stations coordinate on delaying transition when stations would see only small cost savings from transitioning relative to their expected lost revenue. In such cases the game becomes a classic Prisoners' Dilemma, and although each station would like to lower its costs, neither does in equilibrium. When, on the other hand, stations face large cost savings from switching early relative to the expected gain of viewers from the other stations from delaying, stations coordinate on switching early. Non-coordination outcomes are also possible, and are made possible by asymmetries in the costs and benefits of switching among the stations in a market.

The model suggests several observable implications, which we explore and test using the stations' decisions and other data from the television broadcasting industry. In general, both casual and more formal examinations of the data yield results that are in line with the prediction of the model. Upon further refinement of the work begun in this preliminary version of the paper, we hope to provide insight into the stations' decision making process that will ultimately help market observers and regulators better understand the calculus of the industry.

The paper is organized as follows. We provide background information in the next section, covering regulatory, engineering, and economic aspects of the broadcast television market. We then discuss the DTV transition and the timing of the stations' decisions of when to switch off analog broadcasting. We next present our theoretical model of the decision game and derive its implications. We introduce the data and perform empirical tests of our theory in the following two sections. A final section concludes.

Background

The broadcast TV market

Regulatory Aspects

The 2009 DTV transition of broadcast TV from the NTSC to ATSC technical standard reflects import themes found in the regulatory history of broadcast. From its inception, broadcast TV power at reaching mass markets was recognized creating demands and competition for its use balances between feasibility of existing state of the art, accommodation of incumbent technologies, and the need to maximize the beneficial use of the radio spectrum.

² Various industry sources provide monthly estimates of electricity cost savings per station ranging from several thousand dollars (Seder, 2009) to \$20,000 (Daily Press, 2009) and higher (Konfrst, 2009). The figure for PBS is from DiPaolo (2009).

The early age of television broadcasting was a chaotic time full of exciting advancements in technology and great experimentation, when the state of technology and laws of physics alone regulated radio use. Absent a regulatory structure, radio experimenters pushed the limits of the technology into areas that profoundly impacted commerce, entertainment, and the public good. Having played a role in both averting³ and contributing to major disasters in the early 20th century, Congress focused increased scrutiny on the use of wireless spectrum and with the passage of the Radio Act of 1912 first established a system of “licensing” the use of radio spectrum under the Commerce Department for largely maritime safety reasons.⁴ In addition to providing a check on users compliance with the legislation, the licenses served as a precursor to a system of government grants that constituted both a permission for the use of spectrum under certain conditions, but also rights to certain protections from “interference”.⁵ By the early 1920's the broadcasting use of radio technologies had expanded so rapidly that more than 500 radio broadcasters filled the country on a single frequency,⁶ despite the fact that the 1912 Act did not contemplate broadcasting use and broadcast licensing was initially limited solely to two frequencies--one being reserved solely for crop reports and weather forecasts.⁷ Significant Court losses, growing economic value and demand for spectrum use, and mounting concerns over interference and disruptions of the expectations of use of spectrum⁸ all challenged the early regulatory structure. These and other factors drove the passage of the the Radio Act of 1927 and its successor legislation the Communications Act of 1934 that established the Federal Communications Commission as the regulator of broadcast and other uses of radio spectrum.⁹

The Congress' goals and jurisdiction for the FCC were defined broadly in the Communications Act and from its inception the FCC regulated both market and engineering aspects of broadcast use of

³ After the actions of a single wireless operator saved the lives of 1200 people victims of a shipping accident in 1909, Congress passed the Wireless Ship Act in 1910 requiring wireless radio equipment with a range of one-hundred miles to be installed all U.S. ships traveling over two-hundred miles off the coast and carrying over fifty passengers.

⁴ Observers of the events leading up to the tragic loss of life in the sinking of the RMS Titanic urged changes internationally and in the U.S. to tighten procedures for the use of radios on vessels. The Radio Act of 1912 was passed largely in response to these concerns and required all seafaring vessels to maintain 24-hour radio watch and keep in contact with nearby ships and coastal radio stations, and mirrored the international treaty law negotiated in London of 1912 at the International Radiotelegraphic Convention. Radio Act of 1912, P.L. 264, 62nd, 37 Stat. 302 (1912).

⁵ Hazlett and other commentators observe that the rights and responsibilities associated with spectrum use were of chief concern at the time. Thomas Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 *Journal of Law and Economics*, 133, 145 (Apr. 1 1990)

⁶ Thomas Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 *Journal of Law and Economics*, 133, 145 (Apr. 1 1990)

⁷ The 1912 Act delegated the regulatory powers over radio communication to the Secretary of Commerce and Labor.

⁸ Secretary of the Department of Commerce, Herbert Hoover, played a strong role in shaping radio, despite Court loses that limited federal jurisdiction over radio licensing. In particular the Courts invalidating of Hoovers denials of broadcast licenses for lack of standards, and later for federal jurisdiction outright under the existing statute hastened the legal changes establishing the modern federal regulatory structure for radio use. *Hoover v. Intercity Radio Co.*, 286 Fed. 1003 (App. D.C. 1923); *US v. Zenith Radio Corp.*, 12 F. 2d 614 (N.D. Ill. 1926). The decision in *US. v. Zenith Radio*, marked what is described as the “breakdown of the law” period. described by commentators as the death-knell of the burgeoning private market and judicial adjudications approaches and christening of the federal “command and control” approach to spectrum management. See Thomas Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 *Journal of Law and Economics*, Apr. 1 1990 133-175 (discussing the history of market mechanisms for spectrum use and rejection in favor of the federal regulatory “command and control” approach).

⁹ Communications Act of 1934, P.L. 416, ch. 652, 48 Stat. 1064 (June 19, 1934).

spectrum.¹⁰ Declaring that “no person shall use or operate any apparatus for the transmission of energy or communication or signal by radio ... except under and in accordance with the Act and with a license” Congress intended to bring radio use under clear federal control in order to encourage the larger and more effective use of radio in the public interest, convenience, or necessity but prohibit the outright ownership of spectrum. Under this Congressional mandate incorporating prior broadcasting determinations made under the 1927 Act by the Federal Radio Commission, the FCC implemented a variety of regulatory policies intended to foster the continuing growth of broadcasting and prevent interference between stations. The licensing of broadcast stations geographically by service, frequency and power, resolutions of denials or revocations of licenses, limitations on parties that may hold licenses, and the market structures established by 1941 provided the framework that remains today. In a case challenging the FCC's power to establish rules related to “chain broadcasting” by networks of stations, the Supreme Court upheld the FCC's flexibility in implementing its broad mandate, concluding that the FCC's jurisdiction was not limited to the engineering aspects of radio use but were comprehensive powers to promote and realize the vast potentialities of radio through “such rules and regulations[,] restrictions and conditions, not inconsistent with law, as may be necessary to carry out the provisions of th[e] Act.”¹¹

The licensing of broadcast television prior to the adoption of the NTSC technical standard was classified as “experimental” mirroring the state of the technical art at the time. The FCC's standard selections have always reflected difficult balances between feasibility of existing state of the art, accommodation of incumbent technologies, and the need to maximize the beneficial use of the radio spectrum. The great diversity of “television” technical solutions for a system with the live transmission of sound with moving images that simulated motion (at least 12.5 frames per second) drove the FCC to address the conflicts among companies introducing nationwide service. The FCC formed the National Television System Committee (NTSC) in 1940 to select a technical standard and in 1941 commenced commercial licensing of broadcast television stations under the committee's adopted standard for black-and-white television, the NTSC Standard.¹² Technical advancement in color technologies later required the FCC to reconvene the NTSC in 1950, and in December 1953 the NTSC adopted a “compatible color” standard that was compatible with existing NTSC black-and-white television sets. The FCC had provisionally approved in its Joint Technical Advisory Committee (JTAC) a different color standard that was not backward compatible with the existing standard that would have taken advantage of new technologies exploiting the ultra-high frequency (UHF) band. Initially the FCC would have allowed the prior B&W standard to become obsolete as consumers purchased color TVs that would use both different spectrum and an incompatible technical standard—naturally making it possible to reclaim the VHF band as attrition occurred--, but in the two years the standard was being considered the number of black and white VHF tuning TVs in the marketplace exploded from under a million sets in 1948 to over 10 million by 1951. Recognizing that making the millions existing sets in the market obsolete would constitute a significant burden for consumers the FCC recommended the

¹⁰ The FCC's authority to “consistent with the public interest, convenience, and necessity, make reasonable regulations” was not limited solely to the enumerated statutory provisions . See *National Broadcasting Co. v. United States*, 319 U.S. 190, 217 (1943) (upholding the broad reading of the FCC's regulatory power as extending beyond the technical engineering characteristics of radio spectrum management).

¹¹ *National Broadcasting Co. v. United States*, 319 U.S. 190, 217 (1943) (citing the statute).

¹² In spite of other competing standards NTSC adopted the 1936 recommendation made by the Radio Manufacturers Association (RMA).

NTSC identify a compatible color standard that would protect the value of the investment consumers had made in the still relatively new NTSC black and white TV technology. Thus respecting consumers' existing investments in equipment was a deciding factor even in the selection of the modern analog television NTSC standard.¹³

Wireless Engineering and Physics

Two separate tracks of technology, 1) the generation and display of TV images using television cameras and TV sets, and 2) the radio-frequency (RF) transmitters and receivers that carry signals over the air had evolved by the early thirties and reflect much of the modern techniques and fundamentals still in use today. The engineering fundamentals continue to play a role in the decision making of broadcast entities.

Major discoveries and advances of the early 20th century in the areas of physics and material science, in particular the discovery of the photoconductive qualities of selenium in the late 1800's, provided the technical foundations for television broadcasting for the next 75 years. Techniques for capturing and reproducing graphical images included both mechanical as well as electronic components but by 1934 the fundamental technologies for modern television using a solely electrical process had already emerged.¹⁴ The radio engineering techniques to deliver the prepared moving images and sound also advanced greatly in the early age of radio. The ability to manipulate radio waves to carry information had developed by the time the regulatory structure had congealed in the early '30s and the fundamentals of wireless engineering were understood and were greatly enhanced during wartime in the 1940's.

A complete discussion of TV broadcast engineering is beyond the scope of this paper but three fundamental RF engineering considerations are helpful in understanding the technical aspects of the Digital TV transition relevant to the strategic interests of broadcast entities. Each feature takes advantage of physics aspects of how radio waves propagate and are manipulated to carry information using radio waves.

First, spectrum propagates through space and **loses** energy as it travels away from its source, producing a dependency between the geographic area reception is possible from a transmitter at a given **power level** transmitted.¹⁵ The more energy transmitted the greater the area reception of a signal is possible. Broadcast TV transmitters typically transmit thousands or millions of watts and provide coverage over hundreds of miles.

¹³ The first broadcast of a program using the NTSC "compatible color" system was an episode of NBC's *Kukla, Fran and Ollie* on August 30, 1953. While the broadcast was announced to the public it could only be seen in color at the network's facility.

¹⁴ See Wikipedia, Philo Farnsworth, available at http://en.wikipedia.org/wiki/Philo_Farnsworth (discussing the inventor of the first fully electronic [television](#) system).

¹⁵ The reduction of power density as radio waves propagate away from their source, known as path loss, results from a variety of conditions including *propagation losses*, *absorption losses*, and *diffraction losses*. Radio applications typically evaluate "path losses" using calculations of free space path loss in dB expressed below with f and d as frequency in MHz and distance in km, respectively.

$$\text{FSPL(dB)} = 20\log_{10}(d) + 20\log_{10}(f) + 32.44$$

Spectrum propagates through space undulating in waves, and the physical properties of spectrum differ with the length of the waves—particularly waves of longer **wavelength** travel farther than those of shorter length at the same power. Radio waves are also described in terms of number or **frequency** of undulations the wave completes in a given period, typically measured in Hertz (Hz).¹⁶ TV broadcast signals received by consumers are broadcast over a broad swath of frequencies.¹⁷ TV broadcast's first home was in the very-high frequency (VHF) band. Signals in this band have long wavelengths that travel the farthest at the lowest power levels and are able most able to reach viewers in mountainous or areas with dense foliage. TV broadcast signals in the ultra-high frequency (UHF) band typically require more power to provide service over the same area of an equivalent VHF signal, however, because of the number of common sources of significant interference in the VHF band, UHF broadcast signals can benefit from a more interference free environment.¹⁸ Business practice and consumer equipment typically identify the broadcast frequencies by “channels” which hide the complexity of the 6 MHz increments the licenses are allocated to, and provide for the convenient grouping of VHF stations from channels 2-13, and UHF stations in the channels 14 and above.¹⁹

Low VHF Channel	Lower edge Frequency in MHz
2	54

¹⁶ Standard equation for the relationship between frequency and wavelength is as follows: $f * \lambda = c$ where:

f = frequency in Hertz (Hz = 1/sec)

λ = wavelength in meters (m)

c = the speed of light and is approximately equal to $3 * 10^8$ m/s

Two useful shortcuts for calculating wavelengths in meters and feet are as follows:

A complete discussion of calculations wavelengths would include a discussion of material properties of components, but is beyond the scope of this paper.

¹⁷ The lowest frequency currently allocated for broadcast in use is channel 2 54 MHz and the highest frequency in the UHF for Ch51 is 692 MHz.

¹⁸ The requirement for higher for UHF frequencies is discussed in Appendix A of the OET Bulletin No. 69 and the Advanced Television System's Sixth Further Notice, as the “dipole factor.” See generally OET Bulletin No. 69, *Longley-Rice Methodology for*

Evaluating TV Coverage and Interference

, (Feb. 6, 2004), available at

http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet69/oet69.pdf. While frequency is not unrelated to the inverse square laws spreading effect of waves and the relationship between size of a receiving antenna apparatus and the amount of energy it can channel, on the basis of physics it is technically inaccurate to say that waves attenuate in free space more at higher frequencies as may be suggested by free space space loss analysis.

¹⁹ The FCC first adopted these channel allotments in an order in 1952, but the regulatory history of the allocation of channel 1 to land mobile and the frequencies between the low-VHF and high-VHF to FM radio broadcast are topics beyond the scope of this paper but not irrelevant to complete understanding of the engineering background of DTV transition. See *In the Matters of AMENDMENT OF SECTION 3.606 OF THE COMMISSION'S RULES AND REGULATIONS; AMENDMENT OF THE COMMISSION'S RULES, REGULATIONS AND ENGINEERING STANDARDS CONCERNING THE TELEVISION BROADCAST SERVICE; UTILIZATION OF FREQUENCIES IN THE BAND 470 TO 890 MCS. FOR TELEVISION BROADCASTING; Part 1 of 4*, Docket Nos. 8736 and 8975; Docket No. 9175; Docket No. 8976, 41 F.C.C. 148 (adopted April 11, 1952).

3	60
4	66
5	76
6	82
6A*	81.5

* FM Broadcast allocated for use between Low and High VHF bands and Ch6 audio can be received on FM radio receivers.

High VHF Channel	Lower edge Frequency in MHz
7	174
8	180
9	186
10	192
11	198
12	204

UHF Channel	Lower edge Frequency in MHz
14	470
15	476
16	482
17	488
18	494
19	500
20	506
21	512
22	518
23	524
24	530
25	536
26	542
27	548
28	554
29	560
30	566
31	572
32	578
33	584
34	590

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35	596
36	602
37*	608
38	614
39	620
40	626
41	632
42	638
43	644
44	650
45	656
46	662
47	668
48	674
49	680
50	686
51	692

Techniques for manipulating or **modulating** radio waves to carry information exploit different physical properties of radio waves. For example, amplitude modulation (AM) and frequency modulation (FM), important standards in radio broadcasting, encode information by manipulating the power level and wavelength of radio waves, respectively. Information can also be encoded using different mathematical approaches to improve the performance, resiliency to interference, or other features. For example, the DTV (ATSC) standard encodes TV signal video and audio information digitally using similar compression and error-correcting techniques used in modern consumer electronics equipment such as (DVD) and Internet protocols. These use of techniques make it possible carry more information with higher reliability compared to NTSC, and at lower power.

Regardless of the modulation or engineering technique the quality of TV reception is heavily dependent on the nature and quality of the TV receiver and antenna. The effectiveness of an antenna to receive TV signals depends, among other things, on the physical size of the antenna matching appropriately with a multiple of the wavelength of the desired signal. In some cases consumers with antennas with only a VHF or UHF component would lack even the appropriate variety of equipment to receive TV transmissions. Moreover, the quality of a receiver can be even more important when overcoming certain kinds of interference or for quality modulation of digital signals.

Industrial Organization (networks, ONO, etc., market share)

The industrial organization of broadcast television reflects both regulatory and business considerations but has predominantly turned on the ownership structure of the entity which holds the FCC license, the “station.” Media ownership restrictions are a complicated area of regulatory practice,

but several considerations can be seen to have influenced the TV broadcast market and influenced broadcast entities decision making.

After broadcast technologies became technically viable, their popularity [exploded] became widespread, and large capital backers began “selling gas stations and buying radio stations.” Capital holders began consolidating ownership to leverage advertising potential and stations' economic growth, beginning with the first commercial radio licensee, Westinghouse Electric, in 1921 when it added two additional stations to its original facilities, KDKA Pittsburg.²⁰ The development of “networks” of stations, known early as “chain broadcasting,” began making identical broadcast content material and events available for simultaneous broadcast by more than one station, as early as 1926 with the formation of the National Broadcasting Company (NBC) network and Columbia Broadcast Service (CBS) in 1927.²¹

NBC's interests and network focus were tied closely to the business strategies of its parent organization Radio Corporation of America (RCA), and its market dominance drew particular ire from its competitors, but in 1938 in response to a request by the Mutual Broadcasting System the FCC commenced its first inquiry into the market structure and competitive issues of the broadcast industry investigating the network domination of NBC and CBS.

In its 1941 report on Chain Broadcasting the FCC described concern that:

[C]ommon ownership of network and station places the network in a position where its interest as the owner of certain station may conflict with its interest as a network organization serving affiliated stations. The danger is present that the network organization will give preference to its own stations at the expense of its affiliates.²²

The FCC expressed its defining view that it had an obligation to restrict the number of commonly-owned stations and to promote diversification of ownership and that a diverse rather than consolidated ownership and operation of broadcast stations would serve the public interest. While noting that the practice was firmly established, the FCC criticized the networks practice owning and operating numerous high-power stations, generally known as “OnO” or “O&O”, and RCA's loss of subsequent litigation eventually did result in the divestiture of station ownership and network operations of the NBC “blue” stations, and the stations acquisition by lifesavers mogul, Edward Noble, and the emergence of the third broadcast network, the American Broadcasting Company (ABC).²³

The changes in regulatory and market structures resulted in an ownership cap on the number of stations a given entity could hold, and networks facing this limitation further consolidated their station ownership interests in the major TV markets, where they continue to hold their ONO stations today. Nevertheless, networks continued to expand their content offering throughout the nation through an

²⁰ Herbert H. Howard, *Multiple Ownership in TV Broadcasting Historical Development and Selected Case Studies* 20 (Arno Press, NY 1979); see also Stephen Davis, *Law of Radio* 140 (McGraw-Hill 1927).

²¹ Howard at 29.

²² Howard at 35; Federal Communications Commission, *Report on Chain Broadcasting* (rel. May 2, 1941) (Washington U.S. Govt. Printing office).

²³ *National Broadcasting Co., Inc. v. United States*, 319 U.S. 190 (1943).

“affiliate” relationship with independent stations. These affiliate stations would contract with networks to broadcast the networks “syndicated” content while maintaining an independent ownership and management structure—if at least formally. Because broadcasting on the same channel in geographic proximity to another broadcaster can result in interference, the division of licenses into geographic “markets” were reinforced by spectrum management concerns for interference in TV channel licensing.

Other technological advancements and regulatory concerns played an important role in the development of TV markets valuation of VHF and UHF stations. By 1948 congestion of the original VHF frequencies posed both licensing and interference management concerns for the FCC, as demand for station licenses continued to swell.²⁴ At the same time military technology advances achieved during World War II showed promise for opening up spectrum in the UHF to new uses such as broadcasting. In addition, as discussed above, advances in camera and display technologies demonstrated that color TV was ready for prime time, and the FCC initially adopted an approach to transition the entire TV market to Color in the UHF by shifting receivers to the UHF band where incompatibilities with VHF B&W TV would render the old standard obsolete. In response the FCC made channels 14-83 available for TV broadcast and relaxed the existing five station ownership restriction to seven stations. However, the FCC provided that no more than five stations VHF stations would be allowed.

When the FCC differentiated the ownership restrictions for VHF and UHF channels in order to promote development and adoption, incentives for expanded ownership emerged and new affiliate opportunities also expanded. Nevertheless, early response and ownership of UHF stations progressed slowly. UHF stations were often viewed as inferior to VHF even after technology shortcomings were addressed.²⁵ As discussed above UHF RF propagation differs significantly from VHF, requiring more power to cover similar areas, in addition to other engineering properties.²⁶ A significant consideration in the value of UHF station ownership also came from the fact that until the passage of 1964 legislation that required UHF tuner technology in all TV receivers, consumers were required either to purchase a “TV-top converter” or a compatible TV receiver, and a new antenna--a precursor to the 2009 U.S. DTV transition.²⁷

²⁴ The FCC froze applications for new broadcast stations in response which was lifted after the release of the of the Sixth Report and Order, *inter alia*, allocating new UHF spectrum.

²⁵ UHF station management, technology and culture has been lampooned in popular culture. See Internet Movie Database, UHF, Motion Picture starring Weird Al Yankovic(1989), <http://www.imdb.com/title/tt0098546/>.

²⁶ Analog TV signal power levels are expressed in terms of “peak of sync” video power, plus an unspecified amount of audio power, and are not directly comparable with DTV power levels that are expressed in terms of “average” (root means square or quadratic mean) power. RMS average power is more useful when calculating electricity usage for OpEx purposes. To convert analog power to rms, in VHF and UHF bands the following formulae are useful, respectively.

$P_{rms} = (P_{peak-vis} * 0.37) + (P_{peak-vis} * 0.1)$; for station channels ≥ 14

$P_{rms} = (P_{peak-vis} * 0.37) + (P_{peak-vis} * 0.2)$; for station channels < 14

²⁷ All-Channel Receiver Act (ACRA) (47 U.S.C. § 303(s)) (1964).

The Switch to DTV

Regulatory Aspects to DTV Transition Strategies

The development of the DTV Standard

From the development of broadcast TV's early engineering and regulatory structure and fixation in the NTSC standard, it has thrived for more than nearly seventy-five years. Despite advances in both technology and regulatory approaches creating opportunities to bring dramatic improvements to broadcast TV, the NTSC standard remained largely unchanged as broadcast TV entered the 1980's. With the convergence of increasing demands for spectrum and business opportunities for advanced TV content and devices, a 20 year process would culminate into the dramatic cessation of the June 12, 2009 realizing dramatic improvements in efficiency for use of radio spectrum, flexibility for broadcasting TV, and in quality of TV viewers enjoy.

In the mid-1980s high-definition TV (HDTV) technologies were demonstrated in Japan that were viewed as a new challenge by U.S. consumer electronics firms already weakened from strong competition beginning in the 1960's from a competitor with a history of market shifting innovations from the beginning of broadcast history.²⁸ Japan's national broadcasting company, *Nippon Hoso Kyokai* (NHK), began broadcasting in the 1980's their HiVision HDTV system, known in the U.S. by its technical MUSE (Multiple sub-Nyquist sampling encoding) moniker. The political impact of the Japanese HDTV standard was a topic in the popular and academic press alike and was cited among examples of Japanese R&D and electronics resurgence.²⁹ Because U.S. production of consumer TV receivers had largely been displaced by Japanese competitors, the threat of an independent Japanese standard posed concern for some U.S. semiconductor manufacturers who continued to compete in the technical context of the U.S. NTSC standard also used in Japan.³⁰ Nevertheless, significant technical and radio channel incompatibilities of the Japanese MUSE with the NTSC standard divided the technical and broadcast community.

In 1982 diverse broadcast industry interests came together to form the Advanced Television Systems Committee (ATSC) to facilitate and develop voluntary technical standards for an advanced television system to replace the aging American NTSC television standard.³¹ The ATSC urged

²⁸ See generally, The Guide To Digital Television CinemaSource, published in The History and Politics of DTV, Technical Bulletin (2002), available at http://www.cinemasource.com/articles/hist_politics_dtv.pdf; Jeffrey A. Hart, The politics of HDTV in the United States Policy Studies Journal, Vol. 22, 1994. Walter B., Emery, National and International Systems of Broadcasting Their History, Operation, and Control (Michigan State University Press 1969) (discussing the history of Japanese broadcast technical innovations); see also NHK, The Evolution of TV-テレビは進化する：日本放送技術の発展小史, available at <http://www.nhk.or.jp/strl/aboutstrl/evolution-of-tv-en/index-e.html> (English and Japanese).

²⁹ See generally, Joel Brinkley, *Defining Vision: The Battle for the Future of Television*, (Harcourt Brace & Company 1998).

³⁰ Some observers argued that crucial areas of TV R&D in the U.S. were beginning to erode at this time and the NHK Science and Technical Research Laboratories (STRL) and other Japanese institutions were already coming to be viewed as strong engineering R&D centers for the technology platforms of modern video technologies.

³¹ The ATSC was formed out of another industry group the Joint Committee on InterSociety Coordination ("JCIC") composed of the Electronic Industries Association, the Institute of Electrical and Electronics Engineers, the National

adoption of the MUSE standard but other U.S. network broadcast interests opposed it as incompatible standard with the NTSC that would require changes to TV channel allotments and pose other technical difficulties. The International Radio Consultative Committee (CCIR) rejected the Muse standard closing the book on the possibility of Muse becoming an internationally recognized standard.³²

Tandem to the industries growing interest in an ATS alternative to NTSC, the FCC was exploring options to fill the need for spectrum with physical properties able to support FCC terrestrial radio users, such as public safety police departments and emergency services users, and delivery and dispatch companies. Having identified unused portions of the allocated broadcast bands as potential homes for new users, the FCC issued a notice seeking comment on opportunities for further sharing between the private land mobile services and the UHF television broadcast service. In its proposal the FCC described its goal of making available additional spectrum to land mobile services in areas where it was most needed, with minimal impact on TV broadcast service.³³ Broadcasters showed significant interest in the proceeding declaring strong intentions to use the frequencies identified for use with an advanced TV technologies.³⁴

The pace of DTV quickened in July 1987 when the FCC issued its First Notice of Inquiry on Advanced Television Service (ATS) and formed the Advisory Committee on Advanced Television Service (ACATS) to review the technical issues and provide a recommendation for a new ATS standard.³⁵ Momentum for a new standard further accelerated with the first congressional hearing on HDTV held in October 1987, and the ACATS call for an open competition for development of the best ATS proposal. The Japanese analog-based Muse standard was an early leader in these trials until 1990, when the FCC on seeing a demonstration of the feasibility of a digital TV solution declared that the new ATV standard would have to support a genuine HDTV signal at least twice the resolution of existing television images and be capable of being "simulcast" on different channels.

ACATS and the ATSC began collaborating on a recommendation for ATS technical specifications. With a decision in early 1993 that a digital standard would be superior to an analog one, a "Grand Alliance" of the former ATV competitors was formed in May 1993 to collaborate on a single

Association of Broadcasters, the National Cable Television Association, and the Society of Motion Picture and Television Engineers. *Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, Fourth Report and Order*, FCC 96-493, MM Docket 87-268 n.2 (rel. December 27, 1996) (ATS Fourth R&O).

³² The United Nations' International Telecommunications Union has three sectors devoted to the radio communications and the role of the International Radio Consultative Committee (CCIR, *Comité consultatif international pour la radio*) is to advise on both spectrum allocations and communications standards such as the Muse broadcast TV standard. The CCIR became the ITU Radiocommunication Sector (ITU-R) in 1992, [xx] years after its founding in 1927.

ITU, Radiocommunication Sector, available at <http://www.itu.int/net/about/itu-r.aspx>

³³ *In the Matter of Further Sharing of the UHF Television Band by Private Land Mobile Radio Services, Notice of Proposed Rule Making*, 101 FCC 2d 852 (1985). The proceeding was opened in response to various petitions and after a 1983 report by the FCC's Office of Science and Technology. *Analysis of Technical Possibilities for Further Sharing of the UHF Television Band by the Land Mobile Services in the Top Ten Land Mobile Markets*, FCC/OST R83-3, October 1983.

³⁴ In his concurring statement Commissioner Henry Rivera stated that the action could stifle the potential of the low-power TV (LPTV) service and argued that insufficient time had been afforded to determine whether the service's spectrum needs. Concurring Statement of Commissioner Henry Rivera to the Notice in the *Matter of Further Sharing of the UHF Television Band by Private Land Mobile Radio Services*.

³⁵ *In the Matter of Advanced Television Systems and Their Impact on the Existing Television Broadcast Service*, MM Docket No. 87-268, 2 FCC Rcd 5125, Adopted July 16, 1987; (rel. August 20, 1987) (ATS R&O).

standard incorporating the best features of each system.³⁶ In November 1995, the ACATS formally recommended the Grand Alliance prototype DTV standard, which the FCC formally proposed in May and adopted with some modifications in December, 1996 as the new terrestrial broadcasting ATSC standard.³⁷

The Digital TV ATSC standard represented significant enhancements to the ailing NTSC standard and held numerous benefits for broadcast stations transitioning to digital.³⁸ Digital techniques in how signals are encoded and decoded over the air offers improvement of the quality of TV reception and its resilience to interference. With digital devices' ability to manipulate "virtual channels," station management can select actual channels flexibly as users are presented only "virtual channels" and actual frequency selections are hidden from the consumer.³⁹ Multicasting allows station management to offer several channels of digital programming at the same time, using the same amount of spectrum required for one analog program, in some cases opening up new affiliate relationships. The standard encodes video signals digitally allowing the flexible carriage of diverse kinds of video, such as standard definition and high-definition video, resulting in better consumer experience and business opportunities for the broadcaster. However, the many benefits come at a cost. As was the case with early UHF television, consumers using an existing NTSC TV receiver must procure a "digital converter box" and possibly a new antenna to view TV after the DTV transition.⁴⁰

Strategic Concerns of the DTV Transition

Channel Allotments, Power, Interference and Spectrum Scarcity

In 1997, the FCC adopted a DTV Table of Allotments that employed a "service replication/maximization" approach to provide existing broadcasters with a DTV channel and power assignments that would replicate the quality and geographic area covered by their existing NTSC analog license.⁴¹ The FCC calculated the power necessary to match (or replicate) the distance to a

³⁶ Grand Alliance was formed with the participation of AT&T (now Lucent Technologies), David Sarnoff Research Center, General Instrument Corporation, Massachusetts Institute of Technology, Philips Electronics North American Corporation, Thomson Consumer Electronics and Zenith Electronics Corporation.

³⁷ *Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, Fifth Further Notice of Proposed Rulemaking*, MM Docket No. 87-268 (rel. May 20, 1996) (proposing ATSC as the DTV standard); *Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, Fourth Report and Order*, MM Docket 87-268, FCC 96-493 (rel. December 27, 1996) (*ATSC Fourth Report and Order*) (adopting ATSC as the new DTV standard).

³⁸ CRS Report 96-401 SPR, Telecommunications Signal Transmission: Analog vs. Digital (discussing the differences between NTSC and ATSC standards); *see generally*, Michael Silbergeld & Mark Pescatore, *The Guide to Digital Television* (2d ed. 1999) (discussing the technical advantages of digital television technology).

³⁹ The reader is directed to the ATSC Standard for PSIP, Document A/65 for more details on the Virtual Channel Table.

⁴⁰ While new TV receivers sold after 2007 were required to include an ATSC tuner if an NTSC tuner was installed, the requirements were phased in gradually over the decade and admitted the possible need for the owner of an HD receiver to purchase a converter box or tuner to watch TV post-transition. *All-Channel Receiver Act (ACRA)* (47 U.S.C. § 303(s)) (1964) (implemented in FCC rules at 47 C.F.R. 15.115c and 47 C.F.R. 15.117b).

⁴¹ *Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service*, MM Docket No. 87-268, *Sixth Report and Order*, FCC 97-115, 12 FCC Rcd 14588 para. 12 (1997) (*ATSC Sixth Report and Order*); *see also* 47 C.F.R. § 73.622. The table was released as an appendix to the Order. *See ATSC Sixth Report and Order*, 12 FCC Rcd at 14693, app. B.

stations existing grade B contour with a DTV signal from all directions transmitted from the stations broadcast antenna at a given height.⁴² The FCC adopted a minimum power level of 50 kW and a maximum power level of 1000, balancing the need to maximize the potential for stations to compete effectively in the provision of DTV services, while ensuring that interference between stations and other services would be prevented.⁴³ Each eligible full-power broadcaster was provided a second channel to broadcast DTV during the interim until the transition was completed, when the Section 3004 of the Budget Act statute required broadcasters to relinquish one of the channels and return to broadcasting on a single 6 MHz channel.⁴⁴

While one of the goals of the DTV transition was to replicate the pre-transition environment for broadcasters, the FCC noted that some broadcasters post-transition channels in some cases would be entirely different than either their original NTSC analog channel or their interim second DTV channel.⁴⁵ In fact the majority of full-power VHF stations would ultimately transition to join existing UHF stations on post-transition UHF channels where different propagation and power effects could affect their strategic decisions. With stations transitioning to UHF channels, two engineering considerations became relevant for the power levels allowed by the FCC. The first was that for stations moving from a VHF channel to a UHF channel higher power levels would be necessary to replicate the original NTSC analog coverage area, given the general rule that higher frequencies require greater power to provide equivalent coverage.⁴⁶ On the other hand, the error correcting and other features of DTV standard allowed the setting of lower power levels than those required for an equivalent NTSC signal.⁴⁷

Reallocations and new users

⁴² NTSC TV broadcast coverage areas are defined by contours that define different levels of quality of reception expected. See generally, O'Connor, R.A., *Understanding Television's Grade A and Grade B Service Contours*, BC-14 IEEE Transactions on Broadcasting 137-143, 10.1109/TBC.1968.265932, (Dec. 1968).

⁴³ *ATS Sixth Report and Order* para. 30.

⁴⁴ See 47 U.S.C. § 336(c) (requiring “that either the additional license or the original license held by the licensee be surrendered to the Commission”); see also *ATS Fifth Report and Order*, 12 FCC Rcd at 12849-50, ¶ 97. The additional channel for DTV operations was only made available to existing broadcasters. See 47 U.S.C. § 336(a)(1); see also *ATS Fifth Report and Order*, 12 FCC Rcd at 12815, ¶ 13; see also Budget Act of 1997, Pub. L. No. 105-33, § 3003, 11 Stat. 251, 265 (1997) (Budget Act). § 3004 (adding new § 337(e)(1) of the Communications Act) (directing that stations “may not operate at that frequency after the date on which the digital television transition period terminates, as determined by the Commission.”).

⁴⁵ *ATS Sixth Report and Order* para. 3 n.6.

⁴⁶ The FCC used procedures and techniques discussed in the Office of Engineering and Technologies Bulletin No. 69 in determining the appropriate power levels and in general discuss the phenomenon as the “dipole effect” defined for low-VHF, high-VHF, and UHF. See OET Bulletin No. 69, *Longley-Rice Methodology for Evaluating TV Coverage and Interference*, (Feb. 6, 2004) (“OET Bulletin No. 69”), available at www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet69/oet69.pdf. The Longley-Rice techniques is a widely used technique for predicting the geographic coverage of a radio system under certain conditions. The software and modeling techniques used by the FCC for the Longley-Rice point-to-point radio propagation model are published in an appendix of NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. with some modifications described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985.

⁴⁷ While some initial decisions suggested that power could be reduced by significant levels, power levels were ultimately revised as more real-world experience informed the engineering and real-world analysis.

Another factor that influenced the selection of transitioning stations' channels was found in the other primary goal of the DTV transition—that of reallocating for other uses TV broadcast spectrum not necessary for DTV. The Budget Act of 1997 required the FCC by January 1, 1998 to reallocate 24 megahertz of spectrum in the UHF channels 60-69 (746-806 MHz band) for public safety services and make the remaining 36 megahertz of the band available for commercial use via competitive bidding (auction) after January 1, 2001.⁴⁸ The FCC reallocated TV channels 63-64 and 68-69 (764-776 MHz and 794-806 MHz bands) on a primary basis for fixed and mobile services available only to the public safety radio services.⁴⁹ The FCC reallocated TV channels 60-62 and 65-67 (746-764 MHz and 776-794 MHz bands) for fixed, mobile, and broadcasting licensing to be assigned by competitive bidding. Broadcasting will have different status in different parts of the 746-806 MHz band. The new licensees in these commercial portions spectrum were to be permitted to provide broadcasting, as well as fixed or mobile services within their service areas with primary status. In addition, the FCC reallocated other spectrum reducing the amount of spectrum devoted to the television broadcast ultimately assigning TV broadcast to a “core spectrum” (*i.e.*, channels 2-51) after the end of the transition,⁵⁰ making channels 52-69 totaling 108 MHz of spectrum available for other new uses.⁵¹

As discussed in more detail below, TV broadcast use of channels outside the core spectrum was prohibited after February 17, 2009, but the delay of the DTV transition date by changes to the statute also delayed the making available of spectrum intended for public safety and commercial wireless uses. The spectrum made available from these reallocations was highly sought after because of its valuable propagation characteristics.⁵² Thus, while broadcasters were “made whole” by the replication of their existing analog service characteristics on their post-transition channel, which viewers could continue to identify as the original TV channel number using “virtual channels.” Nevertheless, in some cases complicated cascading scenarios of stations moving channels to be vacated for use by other broadcasters or non-broadcast users may have also influenced broadcasters decisions regarding when and how to vacate existing analog NTSC channels.

The Mandatory Transition to DTV and Cessation of Analog NTSC Broadcasting

The Congress and the FCC took steps to ensure that consumers would enjoy the benefits of

⁴⁸ Budget Act, § 3004 (adding new § 337(a) and (b) of the Communications Act of 1934, as amended).

⁴⁹ *See Reallocation of Television Channels 60-69, the 746-806 MHz Band*, ET Docket No. 97-157, Report and Order, 12 FCC Rcd 22953 (1998). As discussed in brief above, the FCC allocates spectrum on the basis of services such as for fixed or mobile use by public safety users regulated by FCC Rules in Part 90. In addition the FCC regulates users of some services in some bands on the basis of a priority of rights to protection, as “primary” or “secondary” users. *See* 47 C.F.R. et seq 2.106, Table of Allocations.

⁵⁰ *See Second DTV Periodic Report and Order*, 19 FCC Rcd at 18292, ¶ 33. The “core spectrum” included the low-VHF channels 2 to 4 (54-72 MHz) and 5 to 6 (76-88 MHz), VHF channels 7 to 13 (174-216 MHz) and UHF channels 14-51 (470-698 MHz), but does not include TV channel 37 (608-614 MHz), which is used for radio astronomy research. In order to protect sensitive radio astronomy operations, use of TV Channel 37 was not allowed for NTSC or DTV service. *See DTV Sixth Memorandum Opinion and Order*, 13 FCC Rcd at 7419, ¶ 5; *see also* 47 C.F.R. § 73.603(c).

⁵¹ Channels 52-59 were reallocated for new wireless services in 2001. *See Reallocation and Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-59)*, GN Docket No. 01-74, Report and Order, 17 FCC Rcd 1022 (2002).

⁵² United States Government Accountability Office, *Digital Television Transition: Issues Related to an Information Campaign Regarding the Transition*, GAO-05-940R at 49 (Sep. 6, 2005).

DTV by both encouraging and requiring manufacturers and broadcasters to transition to the new standard. The policies encouraging compliance included licensing opportunities for broadcasters to develop DTV operations on separate channels. Encouraging broadcasters provision of DTV broadcasting and the ultimate goal of transitions all broadcasting to the new DTV standard proved challenging.

Congress in the most significant revision of communications law since the establishment of the FCC, among other things, directed the FCC to provide new licenses to existing broadcasters for the provision of DTV broadcasting under the condition that broadcasters would have to return either the new or original analog license at some date.⁵³ The FCC issued some 1600 licenses⁵⁴ and adopted mandatory dates that stations would have to “transition” to DTV broadcasting and relinquish one of their channels that reflected the size of the markets where the stations were located.⁵⁵ Stations in the top 10 markets would have to transition by May 1, 1999, affiliates in markets 11-30 by November 11, 1999, all other full-power commercial stations by May 1, 2002, and noncommercial stations by May 1, 2003. Congress revisited the issue in the Balanced Budget Act of 1997 codifying new deadlines for the DTV transition.⁵⁶ The transition dates were subject to controversial conditions where “extensions” would be available, notably “if at least 15% of the television households in the market served by the station do not subscribe to a digital “multi-channel video programming distributor” (including cable or satellite services) and do not have digital TV sets or converters.”⁵⁷ Thus if eighty-five percent of households did not have DTV ready receivers or were subscribers of cable or satellite in any given market, the transition in that market would not proceed.

The distribution of licenses to existing licenses proceeded after an unprecedented engineering effort that required a careful selection of geographically sited channel allotments at precise power levels to prevent interference to non-broadcast services and broadcast stations alike. Many DTV license allotments were made in the UHF band where higher power levels were necessary to maintain the equivalent service areas to the existing analog broadcast footprint.

In 2001, then Chairman Michael Powell formed the FCC DTV Task force to track and facilitate Early progress of DTV adoption and preparations for the transition indicated signs of concern. In the Dallas / Fort Worth area, early tests in 1998 by WFAA with DTV resulted in interference to 12-heart monitors at the Baylor Univ. Medical Center interference on ch9. Additionally, stations complained of significant cost and difficulties with funding. KSTP-TV of Minn – ST Paul reported spending approx. \$1.5 mil in 1999 to upgrade its facilities for the transition.⁵⁸ By 2002 75% of the 1240 broadcast stations had failed to meet their DTV construction requirements complaining of a variety of difficulties

⁵³ Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (1996) (adding section 336 to the Communications Act of 1934).

⁵⁴ The DTV spectrum provided was valued between \$11 billion and \$70 billion and the 104th Congress debated whether the FCC should be required to auction the DTV licenses to interested applicants but in the end no auction authority was provided to the FCC in the legislation. Lennard G. Kruger, Cong. Research Serv., *Digital Television: An Overview* at 4 (2006), <http://www.opencrs.com/rpts/RL3126020060822.pdf>.

⁵⁵ *Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, Fifth Report and Order*, MM Docket No. 87-268, FCC 97-116 para. 76.(rel. April 21, 1997).

⁵⁶ Pub. L. No. 105-33, § 3003, 11 Stat. 251, 265 (1997).

⁵⁷ The other conditions included: if one or more of the television stations affiliated with the four national networks are not broadcasting a digital television signal; or if digital-to-analog converter technology is not generally available in the market of the licensee.

⁵⁸ Roger L. Sadler, *Electronic Media Law* at 96 (Sage 2005).

but foremost among concerns were difficulties acquiring new tower approvals with local governments and lack of funding for new facilities. As 2006 approached, the Congress became increasingly concerned that the 85% threshold would not be met and other concerns would prevent a timely transition. Debate began but not simply on extending the previous deadline instead focusing on adopting a new "hard" date that would not be subject to extensions or delays.

On February 8, 2006, the Deficit Reduction Act of 2005⁵⁹ set a new hard deadline directing that:

The Federal Communications Commission shall take such actions as are necessary to terminate all licenses for full-power television stations in the analog television service, and to require the cessation of broadcasting by full-power stations in the analog television service, by February 18, 2009 ...⁶⁰

In 2006 as the date set in the Balanced Budget Act of 1997 approached, Congress had again extended the deadline February 17, 2009 for the transition.

Entering 2008, concerns in Congress again arose regarding the public's preparedness for the February 17, 2009 transition. In its report in November 2007, the Government Accountability Office concluded that no comprehensive plan or strategy to measure progress and results in the transition existed in the federal government., and that consumer outreach efforts were being conducted primarily by private sector stakeholders on a voluntary basis.⁶¹ As the nation entered the last months of the DTV transition, Congress and President Obama's concerns piqued. Citing serious concerns about the NTIA's coupon program⁶² and general preparedness of consumers, the DTV Delay Act was made law extending the deadline an addition four months to June 12, 2009.⁶³

Voluntary Early Transition

In December 2007 in the Report and Order of the Third Periodic Review of the Commission's Rules and Policies Affecting the Conversion To Digital Television (Third Review R&O), the FCC adopted rules to allow stations to transition in advance of the February 17, 2009 date required by statute.⁶⁴ The procedures outlined in the Report and Order provided for "Reductions or Terminations "

⁵⁹ Digital Television Transition and Public Safety Act of 2005 ("DTV Act"). Pub. L. No. 109-171, §§3001-3013, 120 Stat. 4, 21-28 (2006).

⁶⁰ See S. 1932, 109th Cong. §3002(b) (2006) (enacted).

⁶¹ United States Government Accountability Office, *Increased Federal Planning and Risk Management Could Further Facilitate the DTV Transition*, GAO-08-43, November 2007.

⁶² The Department of Commerce's National Telecommunications and Information Administration (NTIA) administered the TV Converter Box Coupon Program authorized in the Digital Television Transition and Public Safety Act of 2005, P.L. 109-171 (2005). Households were eligible to receive two \$40 "coupons" good towards the purchase of qualifying digital converter boxes. During the weeks leading up to the transition significant numbers of consumers were on a waitlist to receive coupons while expired coupons funds were recommitted and the overall total funding for the program neared exhaustion. *See generally* <http://www.ntia.doc.gov/dtvcoupon/index.html>.

⁶³ DTV Delay Act, Pub. L. No. 111-4, 123 Stat. 112 (2009). Press Release, President Barack Obama, Statement of President Barack Obama on Signing the DTV Bill (Feb. 11, 2009), *available at* http://www.whitehouse.gov/the_press_office/StatementofPresidentBarackObamaonSigningtheDTVBill/. Most stations had the option of sticking with the original date and some one-quarter did.

⁶⁴ *Third Periodic Review of the Commission's Rules and Policies Affecting the Conversion To Digital Television*, MB Docket

of an existing service where the change would facilitate certain goals of the transition. The procedures outlined eligibility requirements, required showings to the Commission, and requirements to inform viewers, for early terminations prior to the last 30-days and after. After the DTV Delay Act of 2009 changed the transition date from February 17, 2009 to June 12, 2009, in the legislation directed that the same rules should be applied with some modifications. The procedures vary slightly depending on the service but most importantly how soon a change would occur with respect to the mandated transition date.

Prior to November 19, 2008

The Third Review R&O outlined rules for different service scenarios. The Analog Service Reduction and Termination rules related to the termination of the existing analog NTSC service, and are in effect the early DTV transition of a station.⁶⁵ The procedures for analog termination generally describe the standard for the other service changes. The first is that stations were required to obtain approval from the FCC before making changes. Request were required to be filed 90 days in advance of the planned termination or reduction of its analog service and were required to satisfy that:

- (1) The station demonstrates that its analog service reduction or termination is directly related to the construction and operation of its, or another station's, post-transition facilities; and⁶⁶
- (2) The station notifies viewers on its analog channel about the planned service reduction or termination and informs them about how they can continue to receive the station, as detailed below.⁶⁷

The FCC in the Third Review R&O identified that the record had strongly favored allowing stations the flexibility to permanently reduce and/or terminate their analog service before the statutory deadline if the station's technical facilities and the conditions in its market warranted the change.⁶⁸ Viewer notification was an important component of the early termination procedures and were required to

No. 07-91, *Report and Order*, FCC 07-229 (rel. December 31, 2007) (*Third Review R&O*).

⁶⁵ *Third Review R&O* para. 107.

⁶⁶ Examples identified as "directly related" to the construction and operation of post-transition facilities included: (1) Stations that need to reposition their digital and analog antennas before the end of the transition; (2) Stations that need to add a third antenna to their tower but cannot do so without reducing or terminating analog service because the tower cannot support the weight of the additional transmission facilities; (3) Stations on a collocated tower that must coordinate a reduction or termination with other stations in order to configure their final, post-transition facilities; (4) Stations with equipment currently in use with their analog operations that they plan to use with their digital operations; and (5) Stations that must terminate operation on their analog channel in order to permit another station to construct its post-transition DTV facilities on that channel. *Id.* para. 116

⁶⁷ Notifications were required every day on-air at least four times a day including at least once in primetime for the 60 days prior to the planned service reduction or termination.. The notifications were required to include: (1) the station's call sign and community of license; (2) the fact that the station is planning to or has reduced or terminated its analog or digital operations before the transition date; (3) the date of the planned reduction or termination; (4) what viewers can do to continue to receive the station, i.e., how and when the station's digital signal can be received;2 (5) information about the availability of digital- to-analog converter boxes in their service area; and (6) the street address, email address (if available), and phone number of the station where viewers may register comments or request information. *Id.* para. 117.

⁶⁸ *Id.* para. 109.

commence no fewer than 60 days prior to reduction or termination of the analog signal.⁶⁹ As part of an early transition, stations terminating their analog and commencing DTV service on their analog channel or moving to a new channel for post-transition operations were also allowed to terminate existing digital service on their pre-transition DTV channels prior to the transition date. flexibility to reduce or terminate existing analog or pre-transition digital service prior to the February 17, 2009 transition date where necessary to permit stations to finalize construction of their post-transition facilities.⁷⁰

The procedures also provided for early transitions of satellite stations and most stations with an out-of-core DTV channel to terminate pre-transition digital service and transition directly from their analog to their post-transition digital channel (*i.e.*, “flash cut” approval),⁷¹ move digital channels to new channels,⁷² The FCC viewed favorably these early transitions identifying that they could advance and facilitate the transition by freeing engineering and construction resources for those stations building later and advance the transition by setting in motion “daisy-chains” of early transitions, *i.e.*, as channels are vacated by the departing station they will be freed-up for the incoming station

Early Termination From November 19, 2008 through February 16, 2009

The FCC provided a streamlined notification procedures for stations terminating (analog or digital) within 90 days of the February 17, 2009, transition date (*i.e.*, beginning on or after November 19, 2008). Stations were permitted to terminate analog or digital service within 90 days before the transition date by filing a notification with the Commission. The FCC required the notification be filed 30 days in advance of the planned service reduction or termination and include a showing that the service reduction or termination was necessary for purposes of the transition. The FCC did not require prior approval, but stations were required to notify their viewers on their pre-transition channel(s) (analog and digital) about the planned service change and inform how consumers could continue to receive the station.

Early Termination on February 17, 2009

The DTV Delay Act provided that stations that sought to terminate their analog service prior to the new June 12, 2009 date would be subject to the FCC's existing rules for early termination of analog service.⁷³ For stations that wanted to terminate analog service on February 17, 2009 the FCC waived

⁶⁹ *Id.* para. 114.

⁷⁰ *Id.* para. 118.

⁷¹ *Id.* para. 124.

⁷² *Id.* para. 121. Moving from a pre-transition DTV channel to a post-transition channel was allowed provided: (1) The early transitioning stations will not cause impermissible interference to another station; and (2) The early transitioning stations continue to serve their existing viewers for the remainder of the transition and commence their full, authorized post-transition operations upon expiration of the February 17, 2009 transition deadline.

⁷³ DTV Delay Act, § 4(a) (“PERMISSIVE EARLY TERMINATION UNDER EXISTING REQUIREMENTS.— Nothing in this Act is intended to prevent a licensee of a television broadcast station from terminating the broadcasting of such station’s analog television signal (and continuing to broadcast exclusively in the digital television service) prior to the date established by law under section 3002(b) of the Digital Television Transition and Public Safety Act of 2005 for termination of all licenses for full-power television stations in the analog television service (as amended by section 2 of this Act) so long as such prior termination is conducted in accordance with the

generally Third Review R&O requirements of prior Commission approval, 60 days of viewer notification and 90-day advance notification, subject to certain conditions.⁷⁴ Stations were not required to submit pleadings or engineering in support of waiver requests, as the Public Notice operated as a waiver, and no express grant of the waiver was required. Thus stations that intended to transition and had incentives were generally permitted to transition on the February 17, 2009 date.

Early Termination after February 18, 2009

As discussed above the DTV Delay Act postponed the mandatory analog shutoff date from February 17, 2009 to June 12, 2009 and stations that sought to transition on February 17, 2009 were in most cases allowed to do so subject to a waiver of the *Third Review Report and Order* requirements. However, stations that sought to transition after February 17, 2009 were subject to the requirements of the existing rules. The rules for an early termination 90 days prior to the transition date, then June 12, 2009, did not require FCC approval, but requests that would occur during the period after February 17, 2009 until March 13, 2009 were subject to the rules requiring advance approval and filings showing need. As no waiver was provided for the requirements during this period a *de facto* cooling off period occurred immediately after the transition where stations did not terminate analog transmission and transition to digital only broadcast. As of March 14, 2009, the day 90 days before the new statutory transition deadline of June 12, 2009, the streamlined notification procedures were again available to broadcasters. For stations terminating analog on or after March 14, the FCC required at least 30 days prior notification of termination date and viewer notifications for at least 30 days prior to the termination of analog service. However, transitioning stations after February 17, 2009 were subject to a number of addition public interest obligations.

Affiliates of the major networks – ABC, CBS, Fox and NBC – that wished to terminate analog service prior to June 12, subject to other public interest requirements, were required to ensure that at least 90% of their analog viewers would continue to receive analog service from another major network affiliate through June 12. While the service could consist of continuing regular analog programming from one or more of the major network affiliates remaining on the air until the transition, service was also possible from an “enhanced nightlight” service making available in analog news, public affairs and emergency information from a major network affiliate. The Short-term Analog Flash and Emergency Readiness Act (“Analog Nightlight Act”)⁷⁵ had required the Commission to develop and implement a voluntary program to “encourage and permit” analog television service for a 30-day period after the DTV transition for viewers who had not successfully transitioned by the deadline.⁷⁶ This voluntary program became a component of the requirements after the delay, except for noncommercial stations experiencing significant financial hardship that were allowed to terminate analog service beginning on

Federal Communications Commission’s requirements in effect on the date of enactment of this Act, including the flexible procedures established in the Matter of Third Periodic Review of the Commission’s Rules and Policies Affecting the Conversion to Digital Television (FCC 07–228, MB Docket No. 07–91, released December 31, 2007”).

⁷⁴ *FCC Announces Procedures Regarding Termination of Analog Television Service On or After February 17, 2009: Termination Notifications for February 17, 2009 Must Be Filed By Monday, February 9*, FCC 09-6 (rel. Feb. 5, 2009).

⁷⁵ Short-term Analog Flash and Emergency Readiness Act, Pub. L. No.110-459, 122 Stat. 5121 (2008) (“*Analog Nightlight Act*”).

⁷⁶ The Analog Nightlight Act was enacted on December 23, 2008, prior to the enactment of the DTV Delay Act, Pub. L. No. 111-4, 123 Stat. 112 (2009), which changed the nationwide transition deadline from February 17 to June 12, 2009.

March 27.

Cost-sharing and Coordination Among Broadcasters

DTV licensees that did not receive permission to terminate analog service early subject to the requirements of the *Third Review Report and Order* or abandon their second DTV channel were obligated to maintain both their analog and digital facilities. The maintenance of duplicitous analog and digital facilities were widely cited as highly costly and used to justify early terminations by stations after February 17, 2009.⁷⁷ In some cases engineering concerns prevented the use of the same antennas or siting DTV facilities at the analog location and some stations choose to construct separate facilities. Older analog broadcast transmitters constructed of “tube” based non-solid state components can be particularly difficult to source parts for and can require particular engineering expertise to maintain, creating an additional business risk to maintaining an analog facility in tandem with a operational DTV facility.

Costs of consumer education were a concern of broadcast stations, and in many markets the FCC reported that call centers, walk-in centers, and other efforts were conducted cooperatively by broadcasters. In some cases facilities were run with some stations actively conducting the operations and staff with funds pooled by other broadcasters participating passively in the efforts.⁷⁸ Another example of cost-sharing can be found where stations in some markets pooled resources to address obligations for at least one station to remain analog after a switch to DTV by remaining stations in a market, subject to the requirements of the Short-term Analog Flash and Emergency Readiness Act and early termination rules in the Third Review Report and Order.⁷⁹ A passive firm might weigh an active firm's ability to recoup some value from remaining analog against the costs the firm would incur in maintaining the analog facility.

Game theory model

In this section, we present a simple game theoretic model of the stations' decisions of when to transition to DTV. The purpose of the model is to formalize the notion that stations not only look at their own costs and viewership when deciding to switch early, but also look to the decisions they expect other stations in their market to make. Following the language of game theory, we refer to the latter aspect of the decision as *strategic*. For clarity of presentation, we model a local television market with only two stations, labeled 1 and 2. Each station is assumed to want to maximize its profit during the transition period, and sets aside the impact of its current actions on profits after the transition period. A

⁷⁷ An FCC official discussing its complaint driven approach for post-transition enforcement efforts against stations failing to terminate analog service, cited the significant costs involved in maintaining two separate broadcasting facilities as one reason it was unlikely a station would violate the analog termination.

⁷⁸ In the State of Oregon and in other parts of the country, Public Broadcast stations with existing facilities for handling large call volumes served as the call centers for the entire broadcast market. *See generally* Oregon Public Broadcasting, Digital TV Transition Happens today!, June 12, 2009, available at http://www.facebook.com/note.php?note_id=91606741957.

⁷⁹ *Implementation of Short-Term Analog Flash and Emergency Readiness Act; Establishment of DTV Transition “Analog Nightlight” Program*, MB Docket No. 08-255, Report and Order, FCC 09-2 (rel. Jan 15, 2009) (“*Analog Nightlight Order*”). The FCC reported 121 stations providing nightlight service in 87 markets after the June 12 transition.

station earns profits by selling advertising at rate p per viewer.⁸⁰ Revenue from advertising is pq , where q is the station's viewership. To broadcast, in the short run a station incurs only fixed costs, which are of the form

$$C = F + wx \quad (1)$$

where F includes labor, rent, capital, and other non-power costs, w is the price of electricity, and x is the amount of electricity used, which is a function of technical characteristics of the tower and antenna used.

The action a available to each station is to transition early to digital broadcasting and turn off analog on February 17 (action $a = D$), or to continue analog broadcasting for the time being (action $a = A$). From here on we refer to switching on or before Feb. 17 as switching "early". Some elements of profit are affected by the decisions. In particular, viewership q for a station depends on both stations' actions. If station i switches to DTV early, assume that there is a known probability that something goes wrong with the transition, causing an expected fraction ϕ_i of the original q_i^0 viewers to switch to watching the other station.⁸¹ Thus, the risk a station takes from action D is losing viewers to the other station. The benefit for the station of transitioning early is the power savings: $x(a_i) \in \{x_i^A, x_i^D\}$, with $x_i^A > x_i^D$ (that is, it takes less power to broadcast DTV than in analog). The ad price p , the price of electricity w , and the non-power cost F are invariant with respect to a station's action, the latter because this is a short-run analysis.⁸² There is no economic switching cost, since every station was supposed to be ready to switch in February. Thus, by the time of the current decision to be made, switching costs were already sunk. To keep the theoretic model simple, we ignore the fact that even if all went well with the transition some stations broadcast footprint was planned to change.⁸³ We also leave out the possibility that the superior quality or additional video and audio channels enabled by DTV will attract viewers away from analog stations.

The profit of station i , given its action a_i and its opponents action a_j , can therefore be expressed as:

$$\pi(a_i, a_j) = pq_i(a_i, a_j) - C_i(a_i) \quad (1)$$

where

$$C_i(a_i) = F_i + wx(a_i) \quad (1')$$

$$q_i(A, A) = q_i(D, D) = q_i^0 \quad (2a)$$

$$q_i(A, D) = q_i^0 + \phi_j q_j^0 \quad (2b)$$

⁸⁰ Broadcast advertising prices within a DMA and daypart are largely proportional to the Nielsen point rating of a show (which measures viewership). Negotiations between advertisers and stations can lead to other prices, which we ignore in the model. We also set aside the fact that pq varies by daypart.

⁸¹ For simplicity, we assume there is no leakage of viewership to cable or satellite television. Around the time of the transition, industry observers expected few OTA viewers to switch to cable or satellite (Dickson, 2009). However, Time Warner Cable claimed to gain 80,000 new subscribers from the transition (Wein, 2009).

⁸² We are also assuming that the transition decisions, which needed to be finalized in the space of about a week before February 17, were made without enough time to alter the engineering details of the two options facing the station. In other words, for purposes of our modeling we take ϕ as exogenous.

⁸³ In the empirical work, we relax this assumption.

$$q_i(D,A) = q_i^0 - \phi_i q_i^0 \quad (2c)$$

In (1)-(2), q_i denotes the expected number of viewers for station i during the transition period (we assume the stations are risk neutral).

Given the profit functions, we can now look for the Nash equilibria of the 2x2 game. The payoff bimatrix is:

		Station 2	
		A	D
Station 1	A	$pq_1^0 - C_1(A),$ $pq_2^0 - C_2(A)$	$p(q_1^0 + \phi_2 q_2^0) - C_1(A),$ $p(1 - \phi_2)q_2^0 - C_2(D)$
	D	$p(1 - \phi_1)q_1^0 - C_1(D),$ $p(q_2^0 + \phi_1 q_1^0) - C_2(A)$	$pq_1^0 - C_1(D),$ $pq_2^0 - C_2(D)$

To get insight into the stations' strategies, consider the decision facing station 1. For convenience, define $d_i = p\phi_i q_i^0$, the expected lost revenue from transitioning early, and define $\Delta_i = w(x_i^A - x_i^D)$, the cost savings from turning off analog. If station 1 expects that station 2 will choose action A , then (comparing the payoffs to 1 in the first column of the bimatrix above) 1 chooses to coordinate its actions and also play A if and only if $d_1 \geq \Delta_1$.⁸⁴ This condition states that station 1 is willing to coordinate on A if the expected costs of transitioning (d_1) outweigh the benefits (the cost savings Δ_1). If, instead, station 1 expects that station 2 will choose action D , then (comparing the payoffs to 1 in the second column of the bimatrix above) 1 chooses to coordinate its actions and also play D if and only if $d_2 < \Delta_1$. If not, then the expected benefits of letting station 2 move first (d_2) would outweigh the costs of transitioning and station 1 would play A .

Given that the decision facing station 2 involves the same considerations, it is apparent that Nash equilibrium thus depends on the size of Δ_i relative to d_1 and d_2 , for $i = 1, 2$. The various permutations of the magnitudes boil down to four cases for Nash equilibrium in pure strategies:

Case	Conditions	Nash equilibrium
1	$d_1 \geq \Delta_1$ and $d_2 \geq \Delta_2$	(A, A)
2	$\Delta_2 \leq d_1 < \Delta_1$	(D, A)
3	$\Delta_1 \leq d_2 < \Delta_2$	(A, D)
4	$d_1 < \Delta_2$ and $d_2 < \Delta_1$	(D, D)

There are two other cases possible⁸⁵ for which no pure strategy equilibrium exists (although Nash in mixed strategies do exist) which we ignore for now. The intuition behind the cases is as follows. In case 1, both stations have a small cost savings from transitioning relative to their expected lost revenue, and so neither switches early. Under the parameter region of case 1, the game is the classic Prisoners' Dilemma: both stations would like to end up in the (D,D) cell of the game, where operating costs are lower, but have incentive to stay analog to avoid giving the other firm an advantage. In the other

⁸⁴ We assume that players choose to delay transition whenever they are indifferent between transitioning or not.

⁸⁵ They are $\{d_i < \Delta_1 < d_j \text{ and } d_i < \Delta_2 < d_j\}$, for $i=1,2, j \neq i$.

coordination outcome, case 4, both stations face large cost savings from switching early relative to the expected gain of viewers from the other station if delaying (large enough that the aspect of the Prisoners' Dilemma disappears), and so both switch early.

In the non-coordination outcomes, cases 2 and 3, one of the stations' electricity cost savings outweighs its potential lost viewership, and given that it therefore switches early, the other station's relatively small electricity cost savings leads it to wait, hoping to gain viewers from the other station. The formal game confirms the simple expectation that stations will coordinate on delaying transition when their own cost savings are small relative to risk of losing viewers. Stations will coordinate on transitioning when their prospect of gaining viewers from the other station is small relative to their cost savings. Here the strategic element of the decision (i.e., looking at how the other station's decision affects your station's profit) is apparent. The formal theory also shows a less obvious result: the stations will not coordinate their actions when the expected cost of one station transitioning unilaterally (d_i for station i) falls midway between the electricity cost savings of the two stations.

The next step leading to structural estimation of the parameters of the game, following the New Empirical Industrial Organization literature on empirical estimation of discrete games, would be to add econometric error terms to the profit functions and derive the probabilities of ending up in the various cases. The implied probabilities could then be used for maximum likelihood estimation, as in the entry game of Bresnahan and Reiss (1987), or the method of simulated moments as in Berry (1992). In this preliminary version of the paper, we do not pursue this approach. Instead, we explore whether the strategic implications of the model are borne out in simple reduced form estimations.

The implications of the model are summarized below. Each statement is to be understood holding other factors constant:

1. Each station is more likely to transition early the greater is its Δ . This implies that higher electricity prices and greater power savings from transition make the decision to transition early more likely.
2. Each station is more likely to transition early the lower is its d . This implies that a lower probability of losing viewers, a lower number of viewers potentially lost, and lower ad prices make the decision to transition early more likely.
3. Each station is more likely to transition early the greater the difference between its Δ and its rival's d . In addition to the implications under (1), this further implies that a lower expected number of the *rival's* viewers potentially gained, and (as in (2)) lower ad prices make the decision to transition early more likely.

We explore these implications in our empirical section below.

Data

To analyze stations' decisions and test the implications of our model, we gathered data from a variety of sources. No confidential FCC data are used, although some data come from proprietary industry databases as noted below.

Stations Decisions

The stations' transition decisions are taken from FCC reports stating which stations had

switched to DTV before February 17, which switched on that date, and which had planned to switch then but changed their decision in response to FCC action.⁸⁶

Station Characteristics

In this version of the paper we use only minimal station characteristics. The DMA, state of location, and network affiliation of a station (if any) is from Warren's *TV and Cable Factbook* proprietary database. Only full-power stations are included in our data. The change in the power requirement from switching to digital (measured as the difference in ERP between analog and digital broadcast) is available from public FCC sources.⁸⁷ The FCC also released estimates of the interference a station's digital broadcast was expected to receive from other broadcasts in the area, and we use the fraction of the DTV broadcast footprint so affected.⁸⁸ The electricity cost facing each station is taken to be the state average commercial retail electricity price for 1Q2009, from the Energy Information Administration.⁸⁹ For a subset of the stations, additional information is publicly available from FCC sources: the population covered by the analog and digital broadcasts of the station and the loss in covered population from the DTV transition.⁹⁰

Market Information

We take the Nielsen DMA in which the station broadcasts to be the relevant market. While a station's footprint will not reach every corner of a DMA, and not all stations overlap fully with each other within a DMA, the DMA is the standard market definition for television broadcasting in industry and in academic research (e.g., Brown and Alexander, 2005).

DMA level variables were collected from the *SRDS Media Solutions* database, and include demographic variables from Claritas and ad price data from SQUAD.⁹¹ We supplemented this primary

⁸⁶ See Appendix A to *FCC Public Notice DA 09-221* (February 10, 2009) for stations terminating analog broadcasting before Feb. 17 and for stations planning to terminate on Feb. 17. See Appendices to *FCC Public Notice DA 09-245* (February 13, 2009) for which stations were allowed to actually terminate on Feb. 17.

⁸⁷ The ERP data for most of the stations are from the FCC's second report on broadcast coverage leading up to the transition, available at <http://www.fcc.gov/dtv/markets/report2.html>. Additional ERP data (particularly those for stations that transitioned to DTV before February 17) are from the FCC's Media Bureau Consolidated Database System (CDBS) (see <http://www.fcc.gov/mb/databases/cdbs/>).

⁸⁸ See Appendix B to *MO&O on Recon of the Seventh R&O and Eighth R&O, FCC-08-72*, released March 6, 2008.

⁸⁹ EIA, *Electric Power Monthly*, Table 5.6.B. "Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, Year-to-Date through April 2009 and 2008 (Cents per kilowatthour)," July 10, 2009, http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html#_ftnref1, accessed August 1, 2009.

⁹⁰ The coverage data are from the FCC's second report on broadcast coverage leading up to the transition, available at <http://www.fcc.gov/dtv/markets/report2.html>. The data on population covered is available for 319 stations, for each of which FCC analysis showed that more than two percent of the population covered by the station's analog service would not be covered by its digital service.

⁹¹ The ad prices are the SQUAD Cost-Per-Point (CPP) in the DMA the previous quarter (4Q08). The ad prices per viewer that we use are derived from the CPP as follows. Let p = ad price per viewers, s = SQUAD CPP, r = Nielsen rating points, V = viewing TV households, T = TV households, and A = ad price. The CPP's, when multiplied by the relevant Nielsen rating points, yield the average ad cost in the DMA, and so $A = sr$. Since a ratings point represents one percent of the total number of TV households, we have $r = 100V/T$. Since $p = A/V$, we have: $p = sr/V = 100s/T$. We observe both s and T in the data, and use them to thus calculate p .

source with data from Nielsen on the number of TV households in each DMA⁹² and from the NTIA on the waitlists for DTV converter box coupons at the time of the transition.⁹³ For use in DMA-level analysis, we calculated a weighted average electricity price (see above for source) based on the number of stations located in each state when a DMA spans states.⁹⁴

Empirical Work

We conducted our analysis at two levels: market and individual station. Summary statistics for the data are in Tables 1 and 2.

Market level analysis

We begin with a summary of the market-level transition decisions. Table 3 shows summary statistics for the fraction of stations in the DMA that transitioned before, on, and after Feb. 17. On average in a DMA, 25% of stations switched on Feb. 17. This means that about two of eight stations switched in an average DMA. However, 28% of stations on average desired to switch on Feb. 17, so about 3% wanted to switch but changed their plans in response to the FCC's imposition of additional requirements. On average, 13% of stations had already switched before Feb. 17, giving a total of 38% on average that switched on or before Feb. 17. There are some markets where no station switched, and other markets where all switched early. In both cases, particularly the latter, these are usually markets with few (or even one) stations.

For each statistic, the median is lower than the mean, implying that the distribution is not symmetric. For example, in the median DMA, one of five stations switched on Feb. 17 and only 33% transitioned early. The full distribution is shown in Figure 1. This histogram shows that in 31 markets no station transitioned early, and in 13 markets all did. In the middle range, the weight of the distribution is toward the low end (representing not switching early).

To characterize how the decisions relate to market characteristics, we calculate correlation coefficients between the fraction of stations switching early (on or before Feb. 17) and a host of demographic and economic variables. The results are in graphical form in Figure 2, with the correlation coefficient on the y-axis. Although we will mention which results are in accord with the theoretical model, the presentation is for descriptive purposes only. Some of the correlations may suggest but none imply causality, at a minimum because the pairwise correlation coefficients do not control for other factors.

Panel (a) of Figure 2 shows that switching early is negatively correlated with the size of the market, whether size is measured by the number of stations, the number of households with televisions or total, or the adult population in the DMA. The latter three correlations are significant.⁹⁵ These

⁹² "Local Television Market Universe Estimates" (as of Jan 1, 2009), http://en-us.nielsen.com/etc/content/nielsen_dotcom/en_us/home/measurement/tv_research.mbt.39577.RelatedLinks.13293.MediaPath.pdf, accessed 8/1/2009.

⁹³ NTIA data is from their web site, https://www.ntiadtv.gov/docs/Coupons_and_Households_by_DMA.xls, accessed 2/20/2009.

⁹⁴ We also collected data from Nielsen's report on the state of DTV "readiness" just before the transition. However, since data is calculated only for a small subset of DMAs, we do not use these data in this version.

⁹⁵ Bars in the darker color on the graphs indicate the statistical significance of the correlation coefficient at the 5% level.

measures of market size are proxies for q^0 in d from the theoretical model, so finding that larger markets show less early transitioning is in accord with implications 2 and 3 from the model. Note that with market-level data we cannot distinguish between implications 2 and 3.

In panel (b) we show that early switching displays a U-shaped correlation with age of the household head. For the youngest and oldest age categories, correlation is positive, while it is negative for the middle ages. While this may merely be an artifact of the data, the relationship is remarkable smooth. Given that one recent marketing survey⁹⁶ listed the Baby Boomer generation as the most sought-after advertising demographic, and Generation X as the next most sought after, perhaps the significant negative correlations for these groups reflect broadcasters' fears of losing these high-value viewers. This is the interpretation suggested by implications 2 and 3, since presumably ad price p is highest in areas with large proportions of viewers in these demographic groups. Similarly, panel (c) shows that the highest income brackets also display negative correlation with early transitioning. High income groups are also valuable viewers in terms of ad sales.

In panel (d) we look at the correlations with racial and ethnic composition. The only significant correlation is with the fraction of population that is Hispanic, which is negative. The same marketing report mentioned above⁹⁷ lists Hispanics as the third most sought-after demographic group, and so this finding is also in accord with implications 2 and 3.

We next look in panel (e) at several variables associated with ϕ , the expected fraction of viewers lost from transition. Transitioning early is negatively (but not significantly) correlated with the number of coupon requests, households, and over-the-air (OTA)-only households on the NTIA waitlist at the time of the transition (all taken as a fraction of the number of TV households in the DMA). Since these are measures of lack of readiness for the DTV transition, they serve as proxies for ϕ . Thus, implications 2 and 3 predict the negative correlation we find. Early switching is also negatively correlated with Nielsen's two measures of "unreadiness" for transition, the percentage of partially and completely DTV-unready households. Only the latter is significant, but these provide further evidence in accord with the model.

Finally, we look at correlation with ad prices in panel (f). Implications 2 and 3 predict that higher ad prices will be associated with less early transitioning, and that is the case, although none are significant. Not depicted in Figure 2 is the correlation with electricity prices, which is positive, in accord with implication 1, but is small and insignificant. The unemployment rate in the DMA is not significantly correlated with the transition decision, although to the extent that local economic conditions affect local ad prices the model suggests it might be.

Individual stations' decisions

We turn now to our data on the decisions made by individual stations. There are 1,747 stations we analyze, which are the full-power commercial and non-commercial stations broadcasting at the time of the transition in the 50 U.S. states and Washington, D.C.⁹⁸ Table 2 and Figure 3 show that 36% of these stations transitioned early, switching on or before Feb. 17. Figure 3 reveals considerable

⁹⁶ See "Marketing Executives Networking Group (MENG) Releases First Annual Survey of Top Marketing Trends for 2008", press release dated Nov. 27, 2007, from Anderson Analytics, available from <http://www.andersonanalytics.com/newsfiles/20071127.pdf>, accessed August 14, 2009.

⁹⁷ *Ibid.*

⁹⁸ We do not include the stations from Puerto Rico, Guam, and the U.S. Virgin Islands in our data, although they appear in the FCC data.

variation among networks, however. The three traditional networks were more conservative than most others, switching early only 30-33% of the time. FOX and the CW were about average, while Ion and Univision were far below average (16% and 17%, resp.). PBS and stations in the “other” category (independents, non-PBS public or educational stations, and niche networks) were more likely to switch early than average (44% and 40%, resp.). PBS does not rely on paid advertising to generate station revenue, and its viewers may be less likely to turn to other networks should problems arise due to the unique nature of public programming. Thus, in terms of the model, the expected revenue cost of transitioning is probably lower for a PBS station, which may explain why so many of them wished to switch early.

In Figure 4 we break out the transition decision by the quartile of the size of the television market (based on Nielson rankings of TV markets). As expected, larger markets are associated with a lower probability of switching early.

In the last part of this section, we present the results from some preliminary regressions of the decision to switch early on the station and market characteristics. Table 4 includes three estimations. All are linear probability models with a binary dependent variable.⁹⁹ The regression models allow us to hold constant other factors, allowing cleaner tests of the theory and stronger evidence for (although not proof of) causality. In the first two estimations, the dependent variable is 1 if the station actually transitioned early, regardless of what its earlier plans were. The first two estimations include all stations, including those which had already transitioned before Feb. 17 and thus are not strategic players in the game modeled above. The results from the first two estimations are therefore meant to be descriptive only.

In the first estimation in Table 4, only market size, as measured by the number of TV households in the DMA, and network indicators are included. We also control for the number of stations in the market. Given that we do not vary the number of stations in the model above, we add this variable to control for heterogeneity among markets and have no expectation concerning its sign. In accord with the results discussed above (see discussion of Figure 2(a)), market size has a significantly negative impact on the decision to switch early. The coefficients for the network variables are in accord with the results in Figure 4.

We add demographics and cost variables in the second estimation in Table 4. Even with the additional variables, the adjusted R^2 is relatively low (0.09), indicating that stations’ decisions may be largely based on idiosyncratic factors not captured by the independent variables. Consistent with the correlations we found in the DMA-level analysis, and consistent with the implications of the model, we find negative coefficients for Hispanics, the prime age group, and high-income households (although the latter is not significant). The coefficient for the Asian group is positive, possibly indicating that they are perceived to be a less-desirable demographic segment to advertisers.¹⁰⁰ For broadcasting cost variables, we include the electricity price and the change in ERP, which are both associated with the cost savings from turning off analog broadcasting. We find positive coefficients for both cost variables as expected, but they are insignificant. The coefficients for ad prices and households on the waitlist are not significant.

Since we want to focus most on the strategic aspects of the decision as we have modeled it

⁹⁹ We plan to explore probit models in future work.

¹⁰⁰ The MENG marketing report cited above did not rank Asians among the highly sought after demographic groups. Asian Americans have also been called the “invisible” demographic on-screen in broadcasting (Hong, 2005).

above, rather than outcomes influenced mostly by regulatory decree, we refine our dependent variable and sample for the final estimation in Table 4. We take our dependent variable to be the decision made to transition early, before the FCC intervened in the final week and some stations backed away from their plans they had announced earlier. We also remove from the sample any station that had already transitioned before Feb. 17, since their decision was already made and they are not players in the game modeled in above. We replace the DMA-level market size with a station-specific variable from FCC data on the population covered by the analog broadcast. Note that this figure measures how many people are estimated to be able to receive the transmission, not viewership.¹⁰¹ The same FCC source includes an estimate of the fraction of potential analog viewers that would not be able to receive a digital broadcast (*% Pop. lost by transition*). We also add a variable measuring the percentage of a station's DTV coverage area that is subject to interference from other broadcasts. These latter two variables are both proxies for ϕ_i in the theory model, the expected fraction of viewers lost through the transition. As such, we expect their coefficients to be negative.

To explore implication 3 of the model, we include two variables that pertain to d_j , a station's rival's revenue cost of switching early. We include variables measuring the average of the DTV interference and analog population covered for the other stations in the DMA. Implication 3 suggests that these should have positive coefficients.

As in the first estimations, we control for the number of stations in the market, since the theory was developed for a fixed number of stations (two) and we do not want a changing number of stations in the market confounding our results. We also leave out the demographic variables for race, ethnicity, age, and income, both to avoid using up degrees of freedom with this smaller sample size and because they are insignificant individually and jointly when included.

The results are generally in line with the theory, with a few exceptions. The alternate measure of market size, population covered, is highly significant, in accord with implication 2. More DTV interference leads to a lower propensity to switch early, also in accord with implication 2. Both electricity prices and the change in ERP have negative coefficients, in accord with implication 1, but are insignificant. Ad prices and more viewers losing signal after transition are negatively (but insignificantly) correlated with switching early, in accord with implication 2. The two strategic variables, the population covered by and the DTV interference of the other stations in the DMA, have positive coefficients as predicted by implication 3, although only the former is significant.

One result does not follow the theory. The coupon waitlist coefficient is positive (but insignificant), while implication 2 suggests it should be negative. However, and in summary, there are no statistically significant refutations at the 5% level of our theoretical model.

Conclusions

The model discussed in this paper provides a useful tool for understanding both the effects of DTV transition regulatory efforts on achieving the important policy goals as well as the strategic thinking of the broadcasting entities. The paper explored and tested assumptions about the model using

¹⁰¹ We intend to add station-specific viewership to the dataset, but are still in progress.

the stations' decisions and other data from the television broadcasting industry and presents promising empirical results. In general, our casual and more formal examinations of the data yield results that are in line with the predictions of the model. However, further work in this area could provide greater insight into the stations' decision making process and ultimately help market observers and regulators evaluate the success of the regulatory efforts.

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Variable	Mean	Std. Dev.	Min	Max
stations	8.319	5.204	1.000	27.000
TV households	545,032	831,576	3,940	7,433,820
households	551,089	825,845	4,000	7,546,000
Adult pop	1,105,026	1,733,035	7,600	15,900,000
age0_18	0.002	0.001	0.000	0.005
age18_24	0.056	0.015	0.029	0.142
age25_34	0.158	0.017	0.113	0.220
age35_44	0.182	0.018	0.100	0.236
age45_54	0.207	0.013	0.162	0.271
age55_64	0.170	0.012	0.131	0.212
age65up	0.225	0.035	0.111	0.369
white	0.810	0.124	0.288	0.976
black	0.097	0.107	0.000	0.592
asian	0.024	0.041	0.000	0.507
race_other	0.068	0.067	0.010	0.355
Hispanic	0.096	0.145	0.004	0.940
HH income \$10-20K	0.132	0.027	0.058	0.206
HH income \$20-35K	0.229	0.026	0.133	0.278
HH income \$35-50K	0.196	0.015	0.152	0.229
HH income \$50-75K	0.187	0.024	0.117	0.235
HH income \$75-100K	0.094	0.025	0.048	0.167
HH income \$100-125K	0.030	0.013	0.010	0.083
HH income \$125-150K	0.016	0.008	0.004	0.053
HH income above \$150K	0.023	0.012	0.007	0.085
female	0.512	0.010	0.474	0.532
Commercial Electricity Price	9.539	2.441	6.090	20.890
Unemployment rate	0.064	0.024	0.029	0.274
Ad price/viewer, prime access	0.025	0.023	0.008	0.305
Ad price/viewer, prime	0.046	0.049	0.016	0.635
Ad price/viewer, late news	0.032	0.032	0.012	0.431
Ad price/viewer, late fringe	0.024	0.032	0.007	0.431
NTIA waitlist: coupons	0.036	0.011	0.008	0.080
NTIA waitlist: households	0.020	0.006	0.005	0.042
NTIA waitlist: OTA-only HH's	0.009	0.003	0.002	0.020
% HH's partially unready	12.634	3.919	4.930	22.170
% HH's completely unready	5.400	2.275	1.760	12.240

Table notes: there are 210 DMAs. All variables are observed for each DMA except the Nielsen unreadiness figures, which are available for 56 markets.

Table 1: Summary statistics for the DMA level data

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Variable	Obs	Mean	Std. Dev.	Min	Max
Switched on Feb. 17	1,747	0.235	0.424	0.000	1.000
Desired to switch on Feb 17	1,747	0.260	0.439	0.000	1.000
Switched before Feb. 17	1,747	0.124	0.329	0.000	1.000
Switch on or before Feb. 17	1,747	0.358	0.480	0.000	1.000
TV households (millions)	1,747	0.894	1.204	0.004	7.434
Stations in DMA	1,747	11.559	6.185	1.000	27.000
Network: ABC	1,747	0.122	0.327	0.000	1.000
Network: CBS	1,747	0.126	0.332	0.000	1.000
Network: NBC	1,747	0.128	0.334	0.000	1.000
Network: FOX	1,747	0.110	0.314	0.000	1.000
Network: CW	1,747	0.057	0.231	0.000	1.000
Network: ION	1,747	0.035	0.184	0.000	1.000
Network: PBS	1,747	0.202	0.402	0.000	1.000
Commercial Electricity Price	1,747	9.679	2.783	6.090	20.890
Ad price/viewer, prime	1,747	0.037	0.023	0.016	0.635
NTIA waitlist: households	1,747	0.020	0.005	0.005	0.042
Pop covered by analog broadcast	284	1.667	2.524	0.008	17.708
% pop lost by transition	284	0.108	0.113	0.020	0.714
% DTV interference	1,740	0.017	0.045	0.000	0.565
Δ ERP from transition	1,731	1.087	1.659	-0.999	4.996

Table notes: observations are missing for “Pop covered by analog bcst” because the FCC public released data only for a subset of stations.

Table 2: Summary statistics for the Station level data

Variable	Mean	Median	Std. Dev.	Min	Max
Fraction of stations in DMA that:					
Switched on Feb. 17	0.246	0.200	0.234	0	1
Desired to switch on Feb 17	0.282	0.222	0.257	0	1
Switched before Feb. 17	0.132	0.000	0.206	0	1
Switch on or before Feb. 17	0.378	0.326	0.291	0	1

Table 3: Summary Statistics for Stations’ Decisions to Turn off Analog Broadcasting

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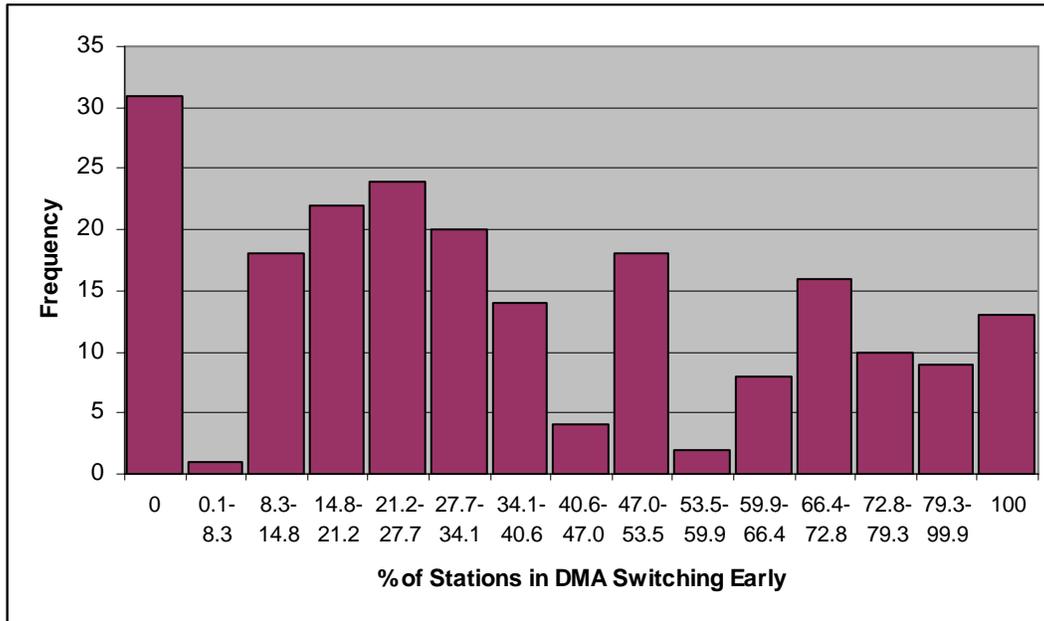
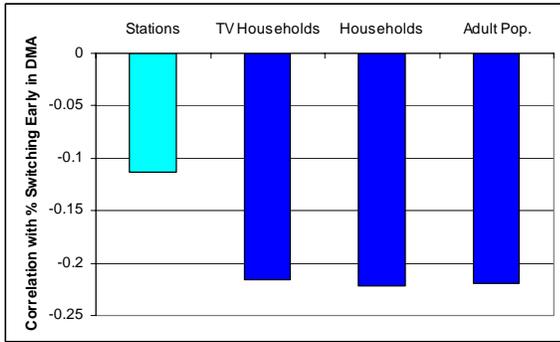
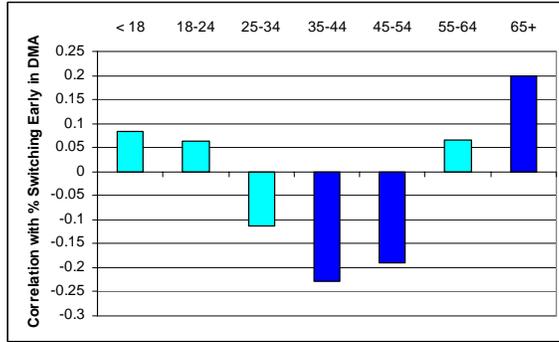


Figure 1: Histogram of Stations' Decisions to Switch Early

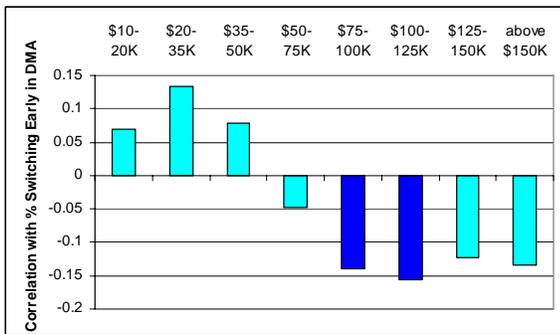
The opinions expressed are those of the authors and do not necessarily represent the views of the Federal Communications Commission or the United States Government.



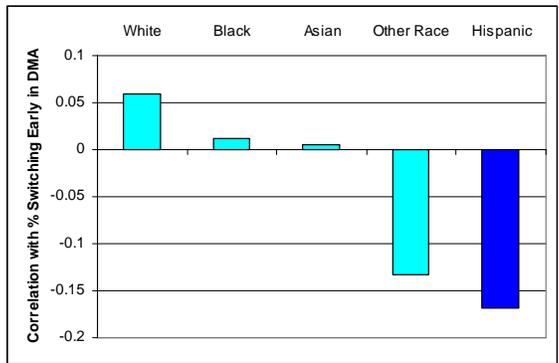
(a) Correlation with Size of Market



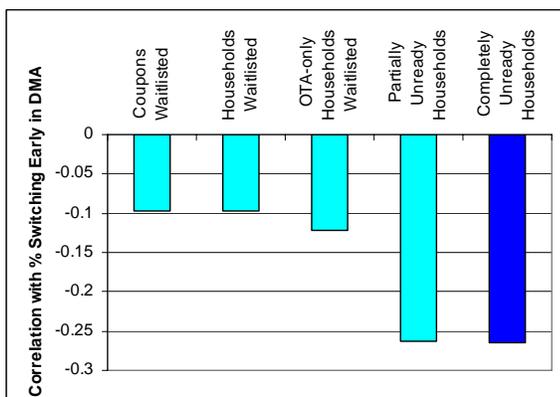
(b) Correlation with Age of Head of Household



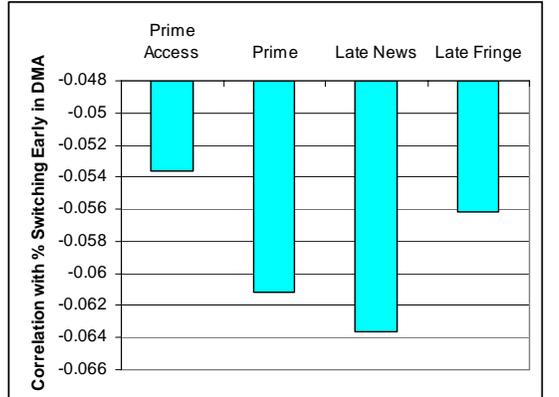
(c) Correlation with Household Income



(d) Correlation with Race and Ethnicity



(e) Correlation with NTIA Waitlist for Converter Coupons and Household DTV Readiness



(f) Correlation with Ad Price per Viewer, by Daypart (SQAD Data)

Note: lighter bars indicate that the correlation is not statistically significant at the 5% level.

Figure 2: Correlation of Stations' Decisions to Stop Analog Broadcasting Early with Various Factors (DMA level data)

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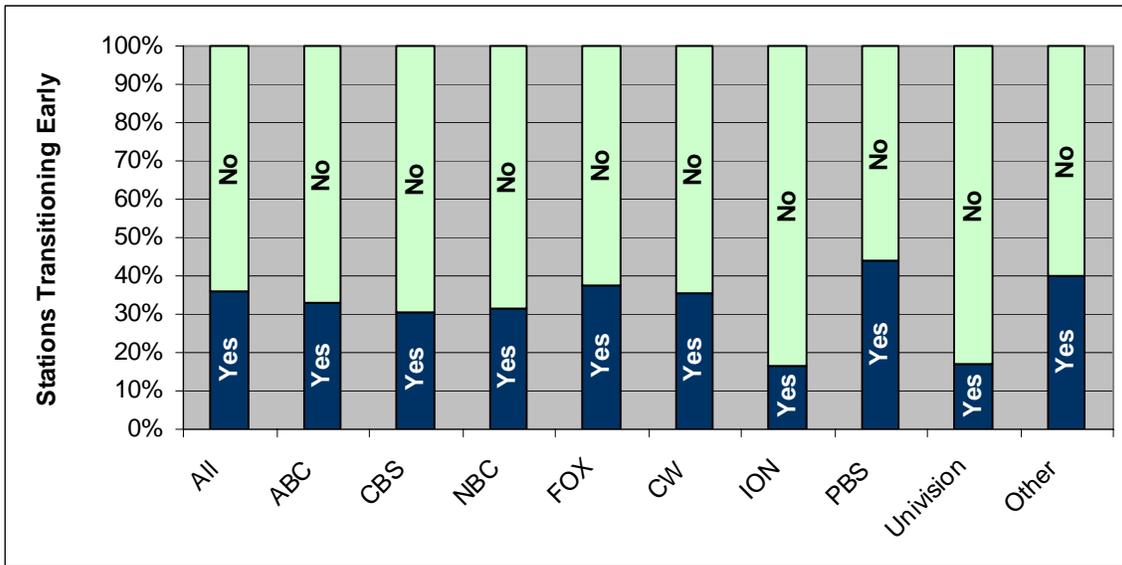


Figure 3: Transition Decisions by Network

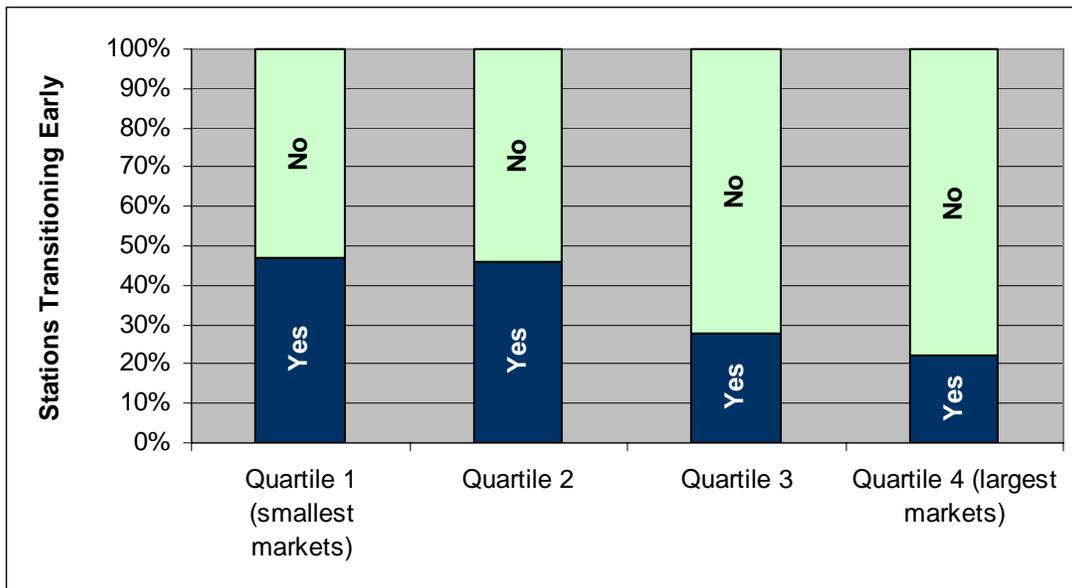


Figure 4: Transition Decisions by Nielsen TV Rank Quartiles

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Variable	$Y_1 = \text{Actually Transitioned Early}$				$Y_2 = \text{Desired to Transition Early}$	
	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
constant	0.420**	0.037	1.475**	0.275	-0.069	0.253
TV households in DMA	-0.087**	0.012	-0.052**	0.015		
Pop. covered by analog b-cast stations					-0.104**	0.025
Network: ABC	0.006*	0.002	0.004	0.003	0.005	0.006
Network: CBS	-0.097*	0.041	-0.120**	0.042	0.110	0.116
Network: NBC	-0.124**	0.041	-0.136**	0.043	0.054	0.115
Network: FOX	-0.109**	0.041	-0.125**	0.042	0.076	0.113
Network: CW	-0.053	0.043	-0.074	0.042	0.076	0.129
Network: ION	-0.053	0.053	-0.058	0.052	0.116	0.157
Network: PBS	-0.222**	0.065	-0.243**	0.064	-0.315	0.165
Black			0.048	0.131		
Asian			0.926**	0.250		
Other race			0.431	0.307		
Hispanic			-0.427**	0.150		
Age 25-54			-1.971**	0.429		
Income > \$100K			-0.850	0.558		
Electricity Price (log)			0.041	0.058	0.012	0.013
Δ ERP from transition			0.007	0.008	0.027	0.019
Ad price/viewer (Prime)			0.103	0.525	-0.800	1.506
% HH on NTIA waitlist			-0.843	2.931	10.213	6.850
% Pop. lost by transition					-0.076	0.259
DTV interference					-1.480*	0.603
Others' pop. covered					0.071*	0.033
Others' DTV interference					1.369	1.048
Adj. R^2	0.042		0.087		0.092	
Observations	1,747		1,731		251	

* indicates significance at the 5% level, ** indicates significance at the 1% level.

Table notes: Regression are linear probability models for the binary dependent variable in the column heading. $Y_1 = 1$ if station transitioned on or before Feb. 17, 0 otherwise. All stations are included in first two estimations. $Y_2 = 1$ if station planned to transition on Feb. 17, 0 otherwise. Only stations not transitioning before Feb. 17 and with publicly available data on loss of analog viewers are included in third estimation.

Table 4: Regression Analysis of Stations' Decisions whether to Transition Early to DTV