# The social value of TV band spectrum in European countries

Thomas W. Hazlett, Jürgen Müller and Roberto Muñoz

Thomas W. Hazlett is a Professor of Law & Economics at George Mason University, Arlington, Virginia, USA (E-mail: thazlett@gmu.edu).
Jürgen Müller is a Professor of Economics at Berlin School of Economics, Berlin, Germany (E-mail: jmueller@fhw-berlin.de).
Roberto Muñoz is an Assistant Professor of Economics at CIDE, Mexico City, Mexico (E-mail: roberto.munoz@cide.edu).

**Abstract**

**Purpose** – *This paper aims to estimate the social gains from an analog TV switch-off in 13 EU countries, focusing on the value of TV band spectrum in alternative uses.*

**Design/methodology/approach** – *By using data from existing mobile phone markets, changes are projected in retail prices for wireless voice services, assuming a reallocation (to mobile telephony) of about 42 percent of TV band spectrum.*

**Findings** – *It is forecast that retail mobile phone tariffs would substantially decline if a transition to digital television led to enhanced availability of VHF/UHF spectrum for wireless telecommunications. Consumer surplus gains offset transition costs by at least 2-to-1, and as much as 45-to-1. These net benefits are conservatively estimated in that other services (apart from mobile telephony) could prove more socially valuable, and because we ignore the considerable increase in video choices the transition could provide. It is also found, however, that wireless operators' profits sharply decline with additional spectrum, due to more intense competition. This suggests a public choice dynamic, often overlooked, that potentially helps to explain the slow pace of the digital TV transition.*

**Practical implications** – *Regulations blocking TV band spectrum from reallocation to non-TV applications ought to be re-examined in light of the associated costs and benefits.*

**Originality/value** – *This paper quantifies, using conservative methods, the cost of current spectrum policies.*

**Keywords** *Television, Radiofrequencies, Telecommunications, Cost benefit analysis*

**Paper type** *Research paper*

## Spectrum costs and the European DTV transition

European Union countries are transitioning their analog television broadcasting systems to digital technology. The migration path has proven difficult to navigate, however, and it is unclear how rapidly the transition will be achieved.

The difficulty can be described as a prisoner's dilemma. Policy makers believe that they are constrained to delay termination of analog broadcasting (a ''switch-off'') until virtually every household can receive digital broadcast TV signals. Consumers without cable or satellite TV subscriptions must therefore be induced to buy digital receivers (and associated equipment, perhaps including antennae). They will hesitate to invest in new technology, however, until there is a compelling reason to do so. The continued availability of analog over-the-air (OTA) TV signals lowers the value of digital OTA broadcasts.

Virtually every jurisdiction is having difficulty solving this stalemate. The UK, for instance, succeeded in inducing just 6.1 percent of households to purchase digital TV sets through mid-2003 – the UK, having digital receivers available since 1998, has been successful in this regard relative to other EU countries (see Table I).

Analog switch-off is potentially valuable to society in that considerable bandwidth is made available for the provision of additional wireless communications. This stems both from the elimination of the analog portion of the transitional analog-digital broadcasting simulcast

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**Table I** Digital TV receiver penetration in European countries

| | *2001 DTV households* | *2003-II DTV households* | *% of total households* |
|---|---|---|---|
| UK | 1,217,000 | 1,510,000 | 6.1 |
| Sweden | 83,000 | 175,000 | 4.2 |
| Spain | 150,000 | 130,000 | 1.1 |
| Finland | 5,000 | 150,000 | 6.5 |
| Germany | 0 | 170,000 | 0.5 |
| The Netherlands | 0 | 8 | 0.1 |

Source: Shulzycki (2003)

regime, and from the fact that digital receivers finely distinguish between adjacent frequencies. This allows digital TV broadcasts to be squeezed more tightly in spectrum space. Instead of leaving one or more ''taboo'' channels (idle spectrum) between broadcast frequencies, each channel can be used without materially degrading reception for viewers using standard television sets.

OTA television is allocated substantial VHF and UHF bandwidth, frequencies highly prized for use in the delivery of wireless telecommunications. The standard European allocation consumes some 469 MHz (see Table II), exceeding the US allocation of 402 MHz (Hazlett, 2001b), and far in excess of the bandwidth allocated mobile telephony, which ranges from under 200 MHz to the 355 MHz allocated in the Netherlands (Hazlett and Muñoz, 2005). By entirely converting to digital terrestrial television (DTT), it is possible to utilize this bandwidth more efficiently.

EU countries use analog channels allocated 7 MHz or 8 MHz. Digital multiplexing and digital adjacent-channel use in a post-transition marketplace could easily offer viewers 100 channels of OTA broadcasting while utilizing less than 200 MHz of the current TV band allocation, leaving more than 250 MHz for the provision of new services such as mobile telephony and wireless broadband.

Yet, gains associated with the provision of new services will not likely commence until the DTT transition is complete, a constraint applied by current regulatory policies in European countries[1] The duration of scheduled transitions, from legislation to analog shut-off, is projected to last a mean of 8.7 years (see Table III). And target dates have not typically been met.

This paper presents estimates of the social value of reallocating TV band spectrum to alternative uses. This allows the costs of delaying such opportunities to be evaluated. We compare the cost of transitioning to a new system, where households can receive digital broadcast signals, with the value of opportunities created when radio spectrum is available for other (non-TV) services. For purposes of this study, we ignore the programming benefits of digital TV which, in any event, may be realized prior to analog switch-off.

## Modeling a digital TV transition

We offer a simple model of the digital television transition, and then estimate how much the TV band spectrum that is made available will change Total Welfare ( = Consumers' Surplus + Producers' Surplus)[2]. The costs of completing the transition in each country are

**Table II** European TV band spectrum allocation

| *Frequencies* | *Bands* | *Channels* | *Bandwidth (MHz)* |
|---|---|---|---|
| 47-68 | VHF Band I | 2-4 | 21 |
| 174-230 | VHF Band III | 5-12 | 56 |
| 470-862 | UHF Bands IV & V | 22-69 | 392 |
| Total bandwidth | | | 469 |

Source: CEPT (2003)

**Table III** Digital television transition plans in Europe

| | *Legislation* | *Soft launch* | *Hard launch* | *Analog switch-off* |
|---|---|---|---|---|
| *Operational platforms* | | | | |
| UK | July 1996 | Sept. 1998 | Nov. 1998 | 2007-2012 |
| Sweden | May 1997 | April 1999 | Sept. 1999 | 2008 |
| Spain | Oct. 1998 | May 2000 | May 2000 | 2007-2011 |
| Finland | May 1996 | August 2001 | Oct. 2002 | 2007 |
| Germany | Spring 2002 | Nov. 2002 | 1Q 2003 | Until 2010 |
| The Netherlands | 1999 | April 2003 | 4Q 2003 | Starting 2004 |
| *Yet to launch* | | | | |
| Portugal | 2000 | 2004 | 2004 | 2010 |
| Switzerland | 2003 | 2004 | 2005 | 2015 |
| France | August 2000 | 2004 | 2005 | Starting 2008 |
| Norway | March 2002 | 2005 | 2005 | Starting 2006 |
| Austria | 2001 | 2005 | 2005 | 2012 |
| Denmark | Dec. 2001 | | | No decision yet |
| Belgium | 2002 | | | 2012 (Flanders) |
| Ireland | March 2001 | | | 2010 |
| Italy | Nov. 2001 | | | 2006 |
| Greece | | | | After 2010 |

Sources: Shulzycki (2003); EU (2005)

assumed to include investments in customer premises equipment (CPE) that will give households the ability to receive a multi-channel subscription service (cable or satellite TV), or off-air digital TV signals. The costs of retrofitting TV stations for digital transmissions is not considered a cost of transition, in that these costs have already been mandated (as per the decision to switch to all-digital broadcasting) and are incurred no matter when the analog switch-off occurs.

The value of additional spectrum for alternative wireless services is projected using a framework developed in Hazlett and Muñoz (2005). A simulation model was calibrated by predicting mobile telephone prices in a 3-equation model (demand, mark-up, and an instrument for quantity) using mobile phone prices and minutes of use across 29 countries (quarterly data, 1999-I-2003-II). After adjusting for demand and supply variables, retail prices are strongly, and negatively, related to the quantity of spectrum allocated to mobile phone licenses. In the Appendix, we describe this estimation procedure in greater detail.

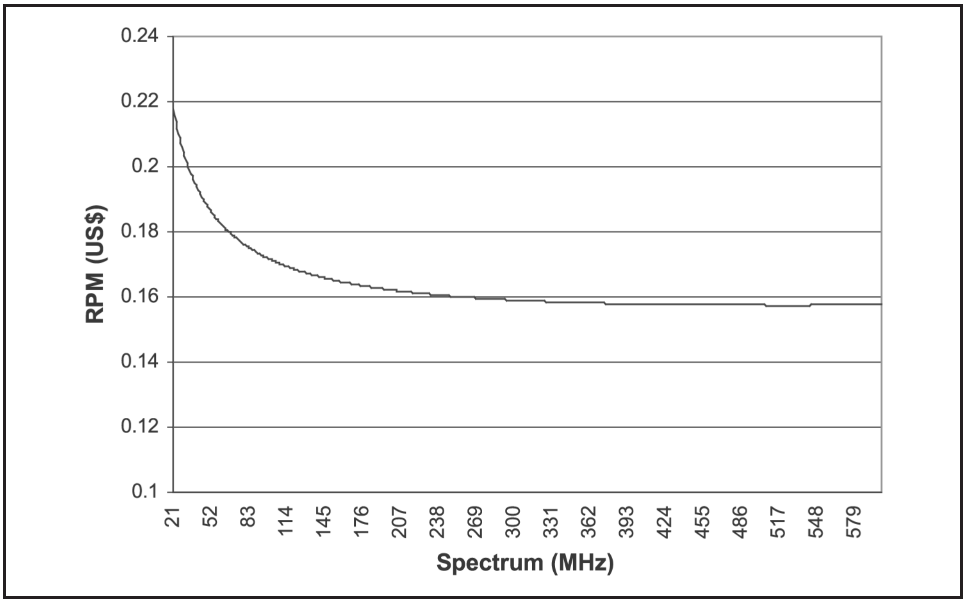
Expanded bandwidth both lowers operating costs and invites entry, increasing competitiveness. The inclusion of non-linear terms permits the relationship between spectrum and service rates (with average revenue per minute of use serving as the proxy) to be estimated, holding other variables at mean values (see Figure 1).

Empirical results obtained from the estimated regressions allow us to predict how wireless voice prices will respond when additional spectrum is allocated to mobile phone licenses. This is a conservative empirical approach in the current application. Because TV-band spectrum could be used for a variety of innovative applications, including wireless broadband connectivity, improvements (price reductions and usage expansion) in existing mobile voice markets represent a lower bound for social welfare gains. Such innovations, however, are not observed, nor are their revenue flows. Hence, plausible estimates are most likely to be generated using data from existing markets.

To be clear, we are not predicting that TV band spectrum would be used for additional mobile voice service. Rather, we estimate the social gain that would result were the spectrum to be used in this market, using this value as a lower bound estimate of the social value from redeployment. Spectrum worth X in providing additional mobile phone service would be worth at least X if used in the most productive way.

In August 2003, Berlin-Brandenburg became the world's first jurisdiction to turn off analog broadcasters in favor of all-digital television (Hazlett, 2003a; GAO, 2004). Regulators presented a choice to the approximately 180,000 households (approximately 9 percent of

**Figure 1** Estimated price-bandwidth relationship




local homes) that did not subscribe to cable or satellite TV service: to continue to have access to broadcast television, either buy an off-air digital signal receiver or subscribe to a multi-channel video provider. With a subsidy program offering vouchers (for one DTT tuner) to about 10,000 low-income households (about 6,000 of which were claimed), political opposition to the switch-over was mitigated.

Viewers were instantly rewarded in terms of increased viewing choices: 12 analog broadcast channels had been available, but 27 digital stations replaced them (taking advantage of digital compression techniques). Meanwhile, channels allocated to television broadcasting diminished from 12 to seven (see Table IV). This implies a 286 percent increase in spectral efficiency[3].

This paper analyzes the consumer gains available from an analog TV switch-off by, in large measure, relying on the experience of the ''Berlin Switch.'' We evaluate the transition, country by country, as if the ''spectrum dividend'' were made available for the use of mobile phone operators. The assumptions made are as follows.

*Costs*

- Every household possesses CPE sufficient to either receive subscription television (cable or satellite) or DTT. The source of this payment (household expenditure or government subsidy) is not considered, although aggregate costs are.
- Only households not currently subscribing to a multi-channel video program distribution (MVPD) service make these additional outlays. This price is assumed to be $300 per household (one time capital expense)[4]. For this amount, a non-MVPD household could be connected to an existing cable or satellite system to receive broadcasting signals (Hazlett, 2001b)[5]. This transition cost could, alternatively, be used for household

**Table IV** Summary of ''Berlin Switch''

| | *Pre-switch* | *Post-switch* | *% change* |
|---|---|---|---|
| Allocated broadcast channels | 12 | 7 | −42 |
| Video program channels | 12 | 27 | +125 |

**Source:** Hazlett (2003b)

purchases of multiple digital boxes (adding a roof-top antenna, if needed). In Berlin, boxes were sold in 2003 for about €129, or $158 (GAO, 2004, p. 17). Set top boxes have been sold throughout Europe for between €99 and €299 in 2003 (Shulzycki, 2003, p. 34).

- The transition to digital and/or subscription TV is assumed to be self-sustaining after investment in initial CPE is made.
- Hence, the cost of transition = (1-MVPD pen.) * Total TV Households * $300.
- TV broadcasters, which have been mandated to broadcast in digital formats, continue to transmit OTA signals. With digital multiplexing, there is an increase in the number of distinct programs broadcast. We do not estimate the increase in value implied by the additional program choices, and assume it to be zero in the cost-benefit comparisons.

*Benefits*

- The bandwidth made available for new services by analog switch-off is determined by analogy to the Berlin Switch, where 12 (analog) channels were replaced by seven (digital) channels. This spectrum reallocation is applied to the entire TV band of the country under consideration.
- European countries allocate 469 MHz of VHF and UHF frequencies to television broadcasting. Applying the 7-to-12 ratio observed in the Berlin Switch, we assume that the end of analog broadcasting would make approximately 200 MHz available in each country. We assume that this bandwidth would be immediately allocated to licenses that allow mobile phone operators to provide 2G and 3G voice and data services[6].
- The social value of this additional 200 MHz used to provide wireless telecommunications is projected using the simulation model calibrated in Hazlett and Muñoz (2005). We simulate the effect of an additional of 200 MHz on the price of mobile voice service in each of the thirteen EU countries which appear in our database (taken from Merrill Lynch, 2003)[7].
- Consumer surplus gains are estimated to be equal to the incremental area beneath the demand curve (and above market price) when prices are lowered and output expands. (Prices are measured in mean revenue per minute of use; output in minutes of use.)
- Producer surplus gains are estimated to be equal to the incremental revenues received (from increased minutes of use, given that demand is elastic across all markets in the sample) minus incremental operating costs. These costs are assumed to equal the same percentage of incremental revenues as observed with initial revenues (using Merrill Lynch data for the ratio of operating expense to total revenue).
- Social welfare is the sum of consumers' surplus and producers' surplus. Where social welfare gains exceed consumers' surplus, producers' surplus over the increment is positive. Where, conversely, the change in consumers' surplus exceeds social welfare gains, producers' surplus is negative as per the assumed change in allocated bandwidth.

*Discussion*

The logic of this analysis is straightforward. Bandwidth no longer used for analog TV transmissions may be productively utilized in supplying alternative outputs. We have estimated the costs and benefits of such a reallocation of radio spectrum, relying on the evidence revealed in the first and only digital TV transition to have been completed, the so-called Berlin Switch. We assume that consumers continue to have access to broadcast television signals, receiving them either by digital OTA transmissions, or via cable or satellite TV links. This implies that there is no cost associated with the transition excepting the investment in equipment to enable reception of these (additional) substitute television signals.

The cost of equipping households without such capability is likely to be far less than the $300 CPE investment we assume[8]. Moreover, the benefits of receiving digital signals and/or subscription television service include far greater choice given a much larger complement of programs (compared to analog OTA broadcasts); these benefits are assumed to be zero. These factors bias the analysis against transitional gains.

There are additional transition costs that are correctly ignored. In that terrestrial TV stations have already been mandated, throughout EU countries, to adopt digital TV transmission technology, these costs are now irrelevant in looking forward to the benefits of spectrum reallocation. In fact, by ending simulcasts (i.e. with analog switch off), public TV stations in the USA estimate that they will realize significant operating-cost savings[9].

*Empirical results*

Before presenting our empirical estimates of the opportunity cost of TV band spectrum, we demonstrate use of our simulation model. Here, we project how an incremental allocation of radio spectrum will be likely to affect price and output in the mobile phone market in the United States (a country not included, unsurprisingly, in our EU sample). Using parameter estimates from the model estimated in Hazlett and Muñoz (2005), which regresses price against a number of variables using quarterly data from 29 countries, we then estimate how increases in spectrum availability reduce price in the USA (or other selected country) by using US-level values for significant explanatory variables such as per capita GDP and the mean price of a 3-minute peak-hour call over the fixed-line network. Dichotomous variables for whether or not the country assigns wireless licenses by auction, and whether the country uses a ''calling party pays'' rule are also included. Market concentration, measured by the Herfindahl-Hirschman Index, is partly a function of allocated spectrum, and is estimated to decrease when bandwidth is added.

Starting values for price and quantity are then predicted at the initial (actual) values, and price is then predicted given changed values for spectrum (assumed) and HHI (implied by the spectrum change). The new price is then used, with the demand elasticity estimated in Hazlett and Muñoz (2005), to predict a new level of output (minutes of use). This yields estimates for changes in consumer surplus (the incremental area under the demand curve and above price) and revenue. The change in producers' surplus is taken from the increase (which may be negative) in revenues minus the increase in operating costs (which is positive, given the increase in minutes of use). This calculation assumes that incremental operating costs are equal to the proportion of operating costs (gross profit ratio) initially observed in the market applied to revenues for additional units of output following the price reduction. In general, the point estimates provided are subject to variance. They are best seen as first approximations of the magnitude of potential social gains from permitting re-use of the spectrum currently allocated for analog television broadcasting.

The result of this simulation approach is seen in Table V. In the US example, the original price per minute of use (MOU) is estimated to be about 13 cents for about 78 billion MOU per month. An additional 200 MHz of bandwidth allocated to wireless licensees results in prices

**Table V** imulating the value of 200 MHz of reallocated TV band spectrum (using the USA as an example)

| *Control variables* | *Units* | *Start* | *End* |
|---|---|---|---|
| Minutes of use | millions/month | 78,340 | Predicted |
| HHI | 0-10,000 | 1,648 | Implied |
| Spectrum | MHz | 170 | 370 |
| Density | inhabitants/sq(km) | 30.27 | 30.27 |
| Auction | 0-1 | 1 | 1 |
| Notcpp | 0-1 | 1 | 1 |
| Agdppc | US$ | 37,353 | 37,353 |
| Fixed line price (3 min. call) | US$ | 0 | 0 |
| Predicted variables | Initial | Final | Change |
| Price per minute | $0.1336 | 0.0695 | −47.97% |
| Minutes of use | 78,340 | 121,674 | 55.31% |
| Δ Consumer surplus | $billions/year | | +76.899 |
| Δ Social welfare | $billions/year | | +52.805 |

Note: Δ = change; variables defined in Appendix
Source: calculations by the authors based on Hazlett and Muñoz (2005)

declining to an estimated 6.95¢ per MOU, with MOU increasing to about 122 billion monthly. The gain in consumer surplus is projected to be about $77 billion per year. In our EU simulations below we assume a five percent (real) social discount rate and provide results in net present values[10]. The change in producers' surplus is negative, meaning that social welfare increases less – about $53 billion per year. The decline in profits is attributed to intensified price competition, which more than offsets the cost-savings to producers from additional bandwidth.

We apply this simulation format to each of the 13 European countries for which we have data. The results of this exercise are reported in Table VI. Columns (a) and (b) show the results of the simulations for each country in net present value, while column (c) shows the projected cost of digital transition. Two aspects are important to our analysis. The first is that, across all countries, there are very substantial estimated net consumer benefits in making analog TV spectrum available for wireless telecommunications service (see column (e)). This is true for countries like Belgium, having near ubiquitous deployment of cable TV service, and for countries like Italy, where cable penetration is near zero. This latter situation raises the cost of transitioning, yet Italian consumers would still benefit enormously from reallocation. From about $500 to $2100 per capita would be generated in net consumer surplus (present value) by transitioning 200 MHz to non-TV services in European countries. These estimates account for the cost of transitioning every household to a digital OTA or subscription TV service, and would yet leave abundant bandwidth (269 MHz) for DTT.

Our analysis of the variance in the country by country estimates reveals that two factors heavily influence the social gains from a digital TV transition: first, the amount of bandwidth currently available for mobile telephony, and second, the degree of competitiveness (measured by the HHI) in mobile telephone markets. The intuition is clear. Because additional spectrum both lowers carriers' costs directly and indirectly lowers prices by providing opportunities for competitive entry, the markets with the most to gain are those that tend to have the least amount of spectrum, and the highest degree of market concentration, to begin with. These markets are projected to produce the largest welfare gains with redeployment of TV-band frequencies.

The second important result is that net benefits are distributed to consumers rather than producers. Wireless carriers (service providers) are negatively impacted by reallocating spectrum from TV to wireless telecommunications. This is seen in the degree to which incremental consumer surplus ($\Delta$CS) is estimated to be considerably higher than Social Welfare ($\Delta$SW) gains, which includes producer surplus (PS) changes. Across countries,

**Table VI** Estimated social benefits (NPV) of re-allocating 200 MHz of TV band

| *Country* | *(a) $\Delta$CS ($MM)* | *(b) $\Delta$SW ($MM)* | *Total HHs* | *Cable TV HHs* | *Sat TV HHs* | *Non-MC HHs* | *(c) Cost Non-MC HHs ($MM)* | *(d) Population (2002, MM)* | *(e) Net $\Delta$CS/person [(a-c)]/d] ($)* |
|---|---|---|---|---|---|---|---|---|---|
| AUS | 10,557 | 2,359 | 3.3 | 1.3 | 1.8 | 0.2 | 60 | 8.0531 | 1,303 |
| BEL | 10,807 | 3,460 | 4.2 | 3.7 | 0.1 | 0.4 | 120 | 10.2964 | 1,038 |
| DEN | 4,408 | 654 | 2.4 | 1.3 | 0.1 | 1 | 300 | 5.3872 | 763 |
| FIN | 9,271 | 2,663 | 2.4 | 1 | 0.3 | 1.1 | 330 | 5.213 | 1,715 |
| FRA | 102,128 | 27,845 | 24 | 2.8 | 2.7 | 18.5 | 5,550 | 59.466 | 1,624 |
| GER | 68,640 | 19,862 | 39.2 | 20.6 | 12.8 | 5.8 | 1,740 | 85.5246 | 782 |
| GRE | 18,265 | 4,841 | 3.8 | 0.8 | 0.1 | 2.9 | 870 | 10.964 | 1,587 |
| IRE | 5,487 | 1,794 | 1.2 | 0.5 | 0.1 | 0.6 | 180 | 3.9789 | 1,334 |
| ITA | 68,698 | 26,316 | 19.4 | 0.1 | 1.2 | 18.1 | 5,430 | 57.6086 | 1,098 |
| NET | 16,064 | 4,096 | 7 | 6.1 | 0.3 | 0.6 | 180 | 16.2172 | 979 |
| POR | 15,950 | 3,549 | 3.4 | 0.8 | 0.4 | 2.2 | 660 | 10.3558 | 1,476 |
| SPA | 44,967 | 16,627 | 12.8 | 0.5 | 1.6 | 10.7 | 3,210 | 40.8474 | 1,022 |

Notes: $\Delta$ = change; CS = consumers' surplus; SW = social welfare; HHs = households; Sat TV = satellite TV; nonMC HHs = households without cable or satellite TV subscription
Sources: BDRC (2001); CEPT (1997); Merrill Lynch (2003)

$\triangle CS$ is from two to five times larger than $|\triangle SW|$, meaning that industry profits sharply decline with retail prices due to the newly available spectrum capacity[11].

Taken together, these results offer a description of the current digital TV transition in Europe and elsewhere. Very substantial gains would be realized were a generous increment of bandwidth to be reallocated from TV to alternative services, yet the gains (as estimated over this increment) would go entirely to consumers. Incumbent wireless carriers would see profits substantially decline. This could explain why, despite large efficiency gains, the path to all-digital television is such slow going. In addition to the prisoners' dilemma, well-organized constituencies expect to be significantly harmed were large increments of bandwidth to be made available for alternative services following analog TV switch-off.

## Conclusion

A transition to all-digital television broadcasting could yield social gains conservatively estimated to fall between about $500 and $2100 per person depending on the particular country under consideration. In addition, a transition from analog TV would yield greater program diversity. Yet, the lure of these social benefits are weak relative to the forces supporting a decades-old equilibrium in spectrum allocation. Indeed, the one country making visible progress with DTT, with Berlin-Brandenburg actually completing the transition (eliminating analog broadcasts) in August 2003, is not moving to reallocate vacated analog TV bands:

> In Germany, government officials and industry participants are implementing the DTV transition largely for the purpose of improving the viability of terrestrial television; officials do not expect to recapture radio spectrum after the transition (GAO, 2004, Abstract).

The simulated market results of TV band reallocation in European countries help explain this regulatory inertia. While the prisoners' dilemma involved in coordinating customer purchases of digital CPE and broadcasters' investments in digital content is well known, it is shown here that incumbent wireless carriers may also fear substantial reallocations of radio spectrum. Such additional bandwidth inputs would lower retail prices substantially. While this produces sizeable consumer surplus gains, it is predicted to lower industry profits (over the 200 MHz increment studied). A further incentive for incumbent carriers to resist the transition to DTT is that licenses could be auctioned, offering service providers a choice between paying substantial sums to obtain access to additional bandwidth, or losing market share to rivals which do[12].

It is commonly observed that incumbent TV licensees strongly resist TV band reallocation. The standard explanation – that TV stations resist reallocation of ''their'' spectrum – is puzzling, however. TV band spectrum is not privately owned, but allocated administratively. Moreover, an allocation for use for non-TV applications would presumably leave TV station rents undisturbed.

An alternative explanation is that television stations resist the use of TV band frequencies not only for TV broadcasting entrants but for suppliers in other wireless sectors as an exercise in regulatory leverage. Having gained the political clout to veto TV band rights assignments to others, broadcasters use their quasi-property rights as bargaining chips. If the property rights were complete, rather than just veto rights, the broadcasters would themselves reallocate their spectrum to higher valued uses. These chips purchase regulatory concessions, such as ''must carry'' rights, yielding TV stations claims on spectrum controlled by cable or satellite TV operators.

The ''digital TV transition'' began in the USA in the mid-1980s when incumbent broadcasters sought to block cellular manufacturers and public safety agencies from using idle TV band frequencies. The promotion of what was initially called ''advanced'' or ''high definition'' television was not driven by consumer demand, but as a strategic reaction to resist spectrum reallocation (Hazlett and Spitzer, 2000). Only when compensated in regulatory favors will parties that have the ability to obstruct productive rights assignments have the incentive to cooperate. The TV band, with exceedingly valuable rights highly fragmented by regulation, results in a classic tragedy of the anti-commons (Heller, 1998; Fennell, 2004;

Hazlett, 2005). While the status quo may therefore be explicable, our estimates indicate it is very far from optimal.

## Notes

1. Reallocation of TV band airwaves could take place in substantial part prior to the end of analog broadcasts by use of, among other mechanisms, ''overlay rights.'' As issued in the PCS band in the USA, such licenses give entrants the opportunity to utilize unoccupied bandwidth while being obliged to limit interference to incumbent users. This approach for TV band frequencies was proposed in the USA by then-US Senator Larry Pressler (the Republican Chair of the Senate Commerce Committee) in 1996, but was not adopted. See discussion in Hazlett (2001a). It should also be noted that once TV band frequencies are available for reallocation government regulators may choose not to allow the bandwidth to be utilized by service providers. This is discussed below in the context of the ''Berlin Switch.''
2. It is important to emphasize that the model predicts the *change* in consumer or producer surplus. For example, a negative impact on producer surplus does not imply negative profits, but means that profits have decreased.
3. This means that 27 TV programs are delivered in 42 percent less bandwidth than was previously used to transmit 12 programs. Economic efficiency judgments require further data.
4. ''The costs for a satellite dish and related equipment are estimated at less than 200 Euro ($246.04). Satellite television service provides viewers in Germany with approximately 125 channels, about 60 of which are in German.'' (GAO, 2004, p. 9).
5. Cable or satellite subscribers are able to access broadcast stations; in an all-digital, post-analog marketplace, these services would continue to deliver broadcast signals. Moreover, the marginal social cost of reception via these systems equals zero. While some government policy might be crafted to guarantee no-cost availability of broadcast TV retransmission via cable or satellite, we note that satellite broadcasting in Europe already operates primarily without subscription fees for viewers. (GAO, 2004, p. 9).
6. Again, this is not a policy recommendation, but an assumption made to establish a lower-bound estimate of the value of spectrum in alternative (non-TV) uses. More flexible use would allow even greater social value to be created, raising our opportunity cost (of delaying the transition) estimates.
7. Some countries in the Merrill Lynch database were not included due to other data being unavailable. These include the Czech Republic, Hungary, Norway, Sweden, and Switzerland. No countries with available data were excluded.
8. We also assume that the transition to digital, once undertaken, is self sustaining. Once consumers have DTV sets or subscribe to cable or satellite services, the system costs no more than current analog broadcasting services, *ceteris paribus*.
9. ''Analog Switch Off (ASO) would save public stations $36 million a year in the electricity costs normally incurred on analog transmission. That figure represents almost 20 percent of the total funding the Corporation for Public Broadcasting distributed to public television stations in Fiscal Year 2003 as Community Service Grants.'' There are 349 public TV stations in the USA. ''Public TV stations study viability of early analog switch off'', *Broadcast Engineering* (17 November, 2003); http://broadcastengineering.com/news/broadcasting_public_tv_stations/. A small number of public stations have already ceased analog transmissions in order to save money. One example is WNVT, located about 60 miles from Washington, DC. ''The prohibitive cost of operating both an analog and digital transmitter simultaneously has caused public television station WNVT-TV, in Goldvein, Va., to shut off its analog transmitter and commit its limited resources to digital television (DTV) transmission . . . Dave Hurd, chief engineer at WNVT-TV, said the move will save them about $5,000 per month in electricity expenses – necessary to operate the analog system alone. The station is not worried about losing viewers because most people in the station's northern Virginia coverage area are getting their TV via cable or satellite.'' ''Hard economics cause WNVT to return to analog spectrum, *Broadcast Engineering* (21 July, 2003); http://broadcastengineering.com/news/broadcasting_ hard_economics_cause/
10. This is a standard assumption, although it is not without controversy in some instances (Hahn, 2004). Critics actually propose lower real social discount rates, which would tend to increase the benefits of spectrum reallocation in this analysis (Parker, 2003).

11. While lower retail prices will reduce profits *ceteris paribus*, here the relationship between profits and prices is theoretically ambiguous. Additional spectrum availability lowers costs and, for a given level of retail prices, increases profits.

12. Even countries not implementing auctions now typically distribute common carrier licenses in exchange for fees.

## References


BDRC (2001), *Development of Broadband Access Platforms in Europe*, BDRC Ltd, London.

CEPT (1997), ''Planning and introduction of terrestrial digital television (DVD-T) in Europe'', paper presented at the European Conference of Postal and Telecommunications Administrations, December.

CEPT (2003), Terrestrial broadcasting data, Electronic Communications Committee of the European Conference of Postal and Telecommunications Administrations, September.

EU (2005), ''Impact of Commission communication on accelerating switchover on individual Member States'', MEMO/05/166, EU, Brussels, 24 May.

Fennell, L.A. (2004), ''Common interest tragedies'', *Northwestern University Law Review*, Vol. 98.

GAO (2004), *German DTV Transition Differs from US Transition in Many Respects, but Certain Key Challenges are Similar*, GAO-04-926T, 21 July, US Government Accountability Office, Washington, DC.

Hahn, R.W. (2004), ''The economic analysis of regulation: a response to the critics'', *University of Chicago Law Review*, Vol. 71, p. 1021.

Hazlett, T.W. (2001a), ''An essay on airwave allocation policy'', *Harvard Journal of Law & Technology*, Vol. 14, pp. 335-567.

Hazlett, T.W. (2001b), ''The US transition to digital television: time to toss the Negroponte Switch'', working paper no. 01-15, AEI-Brookings Joint Center for Regulatory Studies, Washington, DC.

Hazlett, T.W. (2003a), ''Finally, something good on German television'', *Slate*, 7 October.

Hazlett, T.W. (2003b), ''As Berlin's TVs go digital, airwaves lie unused'', *Wall Street Journal Europe*, 24 November.

Hazlett, T.W. (2005), ''Spectrum tragedies'', *Yale Journal on Regulation*, Vol. 22, p. 242.

Hazlett, T.W. and Muñoz, R. (2005), ''A welfare analysis of spectrum allocation policies'', manuscript, November (previous version, AEI-Brookings Joint Center for Regulatory Studies related paper no. 04-18, available at: www.aei-brookings.org/admin/authorpdfs/page.php?id = 1024).

Hazlett, T.W. and Spitzer, M.L. (2000), ''Digital TV and the quid pro quo'', *Business & Politics*, Vol. 2 No. 2, pp. 115-59.

Heller, M. (1998), ''The tragedy of the anticommons: property in the transition from Marx to markets'', *Harvard Law Review*, Vol. 111, p. 621.

Merrill Lynch (2003), *Global Merrill Lynch Wireless Matrix 2Q03: Quarterly Update on Global Wireless Industry Metrics*, 22 September, Merrill Lynch Global Securities and Economics Group, New York, NY.

Parker, R.W. (2003), ''Grading the government'', *University of Chicago Law Review*, Vol. 70, p. 1345.

Shulzycki, A. (2003), ''DTT in Europe: market overview and assessment'', paper presented at DigiTAG Exploratory Meeting, September.


## Appendix

Here we describe the econometric model calibrated in Hazlett and Muñoz (2005). This model is used in the current paper to estimate a lower bound for the value of 200 MHz reallocated from analog television to an alternative opportunity pursuant to a digital television transition. The alternative opportunity was to use the 200 MHz to supply mobile telephone service; this value forms a lower bound on the range of opportunities available, including others that may potentially yield greater value.

The Hazlett-Muñoz (H-M) model examined the relationship between retail price for wireless voice service and a number of economic variables. Price was proxied by RPM, or the average revenue per minute. This and other variables are described as follows:

RPM Revenue per minute in US$ for mobile voice services (proxy for price)

Totmin
Output in the regression is measured as total minutes of use in a month (in millions)

HHI Herfindahl-Hirshman Index in the market (0 to 10,000)

Spectrum
Aggregate bandwidth available in MHz for mobile phone service by all operators in the market

Density
A proxy for capital investment (mean inhabitants per square kilometer)

Auction
Dummy variable = 1 if wireless licenses awarded via auction; 0 otherwise

Notcpp
Dummy variable = 1 if the market not using calling party pays rule; 0 otherwise

Agdppc
Gross Domestic Product per capita adjusted for purchasing power parity, in US$

Fixprice
Mean price of 3-minute call in US$ using fixed network (peak period)

The primary data source was Merrill Lynch (2003), featuring quarterly data from 1999-I through 2003-II. Other sources were: The Economist Intelligence Unit ViewsWire database, the European Commission and the European Radio Communications Office, World Economic Outlook (WEO, IMF) Database (April 2003), and International Telecommunications Union's World Telecommunications Indicators 2002. A database containing 29 countries was constructed, which used all markets where data were available. The countries were distributed as follows: two from Asia, six in Latin America, 17 from Europe, and Australia, Canada, New Zealand and the USA. Variable values are summarized in Table AI.

The theoretical model is defined by two equations: Demand, and Mark Up (or supply). Given that RPM and Totmin are both endogenous in the model and an autorcorrelation problem was detected, a three-stage least squares (3SLS) approach with fixed effects was used. Changes in RPM and Totmin are estimated as a function of exogenous changes in the explanatory variables in the model. For example, the model predicts how an increase in GDP per capita would affect the equilibrium price and quantity in the mobile phone market in a particular country. From a spectrum policy perspective, however, the most interesting explanatory variable is Spectrum.

An increase in the bandwidth (Spectrum) assigned to mobile phone services in a country has multiple effects. First, it directly lowers marginal costs of operators. Second, additional bandwidth is associated with a more competitive market, decreasing HHI. Essentially, the extra spectrum lowers the shadow price of bandwidth, reducing entry barriers. As a consequence, price tends to fall and quantity to rise. H-M shows that consumer surplus increases while producer surplus changes are ambiguous. (This is not only a theoretical result based on a set of assumptions. It is an empirical result arising from the analysis of the database.)

**Table AI** Descriptive statistics

| *Variable* | *Obs.* | *Mean* | *Std dev.* | *Min* | *Max* |
|---|---|---|---|---|---|
| totmin (mil./Month) | 488 | 2788.72 | 8,057.09 | 70.89 | 78,338.39 |
| RPM (US$) | 470 | 0.21 | 0.08 | 0.07 | 0.62 |
| HHI (1-10,000) | 522 | 3,900.69 | 1,058.25 | 1,648 | 6,458 |
| spectrum (MHz) | 522 | 179.46 | 97.63 | 36.4 | 530 |
| density (hab./sq. kms) | 522 | 536.42 | 1,633.80 | 2.46 | 6,832.46 |
| auction (0-1) | 522 | 0.66 | 0.48 | 0 | 1 |
| notcpp (0-1) | 522 | 0.14 | 0.35 | 0 | 1 |
| agdppc (US$/year) | 522 | 21,627.75 | 8,616.87 | 4,953 | 38,278 |
| fixprice (US$) | 504 | 0.10 | 0.05 | 0 | 0.193548 |

Even where the latter declines, however, consumer surplus changes tend to dominate, such that social welfare unambiguously increases when more spectrum is made available to mobile phone operators. The consumer surplus effects can be directly inferred from the impact on equilibrium price and quantity. However, the effect over producer surplus requires having a proxy for the operating costs of the firms. This proxy is built using EBITDA data from Merrill Lynch, 2003.

The estimated H-M model establishes the relationship between price (proxied by RPM) and Spectrum across the whole sample or in a particular country. The former case is illustrated in Figure 1 in our paper. The equilibrium price of mobile phone service is shown to decrease with increases in Spectrum when all the explanatory variables in Table AI (and the fixed effects) have been fixed at their mean sample values.

The H-M model also estimates the effect of different values for explanatory variables in Table AI instead of their mean values. By fixing explanatory variables at the levels observed in a particular country, but changing the Spectrum value, the model predicts the effect of an increase (or decrease) in bandwidth in that country on the price of wireless phone service. This, in turn, yields estimates of changes in consumers' surplus and producers' surplus.

This is the approach used in this paper. Results for the USA are displayed in Table V, and for EU countries in Table VI. Consumer surplus and social welfare can be reported by unit of time (annually in Table V) or in net present value discounting at 5 percent per year (as in Table VI, columns (a) and (b)).

## Corresponding author

Thomas W. Hazlett can be contacted at: thazlett@gmu.edu