The Regulation of Public Service Broadcasters: Should there be more advertising on television?

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November 2017

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May 10, 2017

Abstract

Increased competition for viewers' time is threatening the viability of public-service broadcasters (PSBs) around the world. Changing regulations regarding advertising minutes might increase revenues, but little is known about the structure of advertising demand. To address this problem, we collect a unique dataset on monthly impacts (quantities) and prices of UK television channels between 2002 and 2009 to estimate the (inverse) demand for advertising on both public and commercial broadcasters. We find that increasing PSB advertising minutes to the level permitted for non-PSBs would increase PSB and industry revenue by 10.5% and 6.7%.

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1. Introduction

The number of minutes of broadcast television devoted to advertising is a contentious issue in European public policy. Current EU directives limit the amount of advertising on broadcast television to 12 minutes per hour, but 21 of 28 European sector regulators impose tighter restrictions.[1] In the UK, for example, public-service broadcasters (PSBs) may not exceed a daily average of 7 minutes per hour (8 minutes per hour during peak morning and evening hours), with a hard maximum of 12 minutes per hour in any individual hour; non-PSBs may not exceed a daily average of 9 minutes per hour.[2] Advertising limits are even more stringent elsewhere in Europe, where sector regulators in France and Spain have banned advertising entirely from each country's PSBs (The Economist (2008), The Economist (2009b)), and in Germany where they have considered such a ban (Filistrucchi et al. (2012)).[3] In 2016, The European Commission (EC) considered amending its 12 minute per hour limit in the face of increased competition from internet television services like Netflix, but ultimately decided to leave to let each country's regulators make such decisions.

Two economic factors are paramount for assessing the effects of advertising minute regulations. The first is the effect advertising support has on programming. Because PSBs must deliver audiences to survive, some argue that they have become more like their commercial rivals, resulting in ever-more "Least-Common Denominator" programming (Steiner (1954), Owen and Wildman (1992), Wilbur (2008)).[4] This was the primary factor articulated by President Nicolas Sarkozy behind France's abolition of advertising on their PSBs and for country regulator's opposition to the European Comission's summarized above ((European Comission, 2016, Annex 2)).

The second important factor is revenue. The rise of internet- and multi-channel television coupled with the widespread growth in Internet use in the last 20 years has chipped away at PSB audiences, eroding their revenue base. Combined with

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[1]The countries without additional regulation on advertising minute regulation for either public sector or private broadcasters are Cyprus, Estonia, Finland, Greece, Luxembourg, Malta and Slovenia ((European Comission, 2016, Chapter 6)).

[2]See (Ofcom, 2008, Annex 2, 3). Furthermore, advertisements for certain products (tobacco, alcohol, 'junk' food and prescription medicines) are also proscribed.

[3]The ban on PSB advertising in France implemented in January 2009 removed all advertising on PSB channels during prime time viewing hours, 20.00 - 06.00, with the intent of extending it include all broadcast hours in January 2011. This extension was delayed in October 2010 after reports that the peak viewing ban had reduced ad revenues by half - and that there was insufficient other public funding forthcoming to overcome any additional decreases in revenue. Advertising on PSBs in Spain was banned across in all viewing hours from September 2009. In Germany, while programs can be sponsored, advertising on PSB channels after 20.00 has been banned since 1991. Proposals to ban the sponsorship of non-sports broadcast content and to ban advertising before 20.00 were proposed in 2010 but not implemented.

[4]Wilbur (2008) finds ad-supported commercial broadcasters in the US select programming more likely to appeal to demographics favored by advertisers.

a reduction in governmental support after the Great Recession, revenues for PSBs in Europe have remained relatively flat over the past decade ((European Comission, 2016, Section 3)). In the UK, for example, 2008 revenues to PSBs fell 7.2%, with a further decline of 10-20% in 2009 (Ofcom (2009)). By 2015, PSB revenues had improved slightly on their 2008 levels, but still lagged far behind the double-digit growth levels of non-PSB and Internet advertising (Ofcom, 2016). Stagnant PSB advertising revenue combined with the rising popularity of internet television are threatening the viability of PSBs and requiring sector regulators and/or governments to consider how to fill the gap.[5] While France and Spain have attempted to replace lost PSB revenues through taxes on commercial broadcasters and telecommunications operators, in 2007 and again in 2011 the UK considered amending existing advertising minute regulation in part to help fulfill the purposes of public-service broadcasting.[6]

Understanding the revenue consequences from advertising minute changes is conceptually straightforward: one needs only an estimate of the aggregate demand for (PSB) advertising minutes. Unfortunately, there is little empirical evidence on this basic question. The problem is largely down to data availability: while industry advertising minutes are widely reported by audience measurement firms like BARB in the UK or Gfk in Germany, advertising price data is considered sensitive competitive information and is generally unavailable.[7]

In this paper, we measure the revenue consequences to UK television broadcasters of changed in advertising minute regulation. We utilize a unique, proprietary, monthly dataset from Omnicom Media Group (OMG) to estimate the (inverse) demand for audiences by advertisers. Our data runs between January 2002 and July 2009 and provides information on advertising "impacts" (quantities) and prices for the three main PSB channels - ITV1, Channel 4 (C4), and Channel 5 (Five) - a channel group consisting of the non-PSB channels sold through the Sky sales house (Sky), and a composite of digital "portfolio channels" launched and owned by the PSBs but not subject to the same public-service requirements (ITV2, Film 4, Fiver/5*, etc.).[8] We denote this last group of channels "PSB Digitals." We then use our inverse demand estimates to investigate the the revenue consequences of counterfactual changes in the permitted number of advertising minutes. [9]

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[5]In the UK, the telecommunications and media regulator, the Office of Communications (Ofcom), has expressed concern that some advertising-supported PSBs may relinquish their public-service licenses (and obligations) and compete instead as commercial broadcasters (The Economist (2009a)).

[6]See the discussion at http://stakeholders.ofcom.org.uk/market-data-research/tv-research/arr/.

[7]TV advertising data is typically only readily available in the public domain at a quarterly frequency, and even then only aggregated across channels (e.g. Hendry (1992)).

[8]An "impact" is the viewing of a 30-second advertisement by an individual viewer. We provide a description of the UK advertising market in Section 2 below.

[9]The genesis for the project was a set of reports we helped prepare for Ofcom

We choose to estimate inverse demand equations rather than direct demand equations because UK broadcasters can only influence the quantity of advertising minutes and quality of programming they offer (which together determine impacts). We estimate five equations relating monthly advertising prices to the impacts generated by each the channels or channel groups described above. We include in the model the effects of other factors that shift the inverse demand for advertising, including the supply of monthly Internet impacts and proxies for demand by advertisers (the value of the FTSE 100). As decisions are made by market participants several months previous to ads being aired based on their expectations of prices and impacts in the market, we allow for both dynamic effects (captured by lagged price effects in the inverse demand equations) and measurement error in both prices and impacts. We estimate by Instrumental Variables to address concerns of bias from measurement error, using lagged impacts as instruments.

We find that both short- and long-run estimated own-impact flexibilities are *inflexible*, ranging from -0.04 (for PSB Digitals) to -0.8 (for Five) in the short-run and between -0.39 (for Five) to -1.21 (for Channel Four) in the long-run. Inflexible own-impact flexibilities are analogous to elastic own-price elasticities in that both imply that an increase in impacts yields an increase in channel revenue, controlling for other impacts (prices) in the market (Houck (1966); Huang (1994)).

We evaluate the magnitudes of these effects in a counterfactual analysis that changes the limits on advertising minutes for PSBs and non-PSBs in the UK television advertising market. Following Ofcom's own proposals in this area (c.f. (Ofcom, 2008, p9)), we measure the effects of two proposed policy changes. The first, "harmonizing up," eliminates the difference in regulatory treatment between PSBs and non-PSBs by allowing PSBs to advertise up to a daily average of 9 minutes per hour, the outcome of which Ofcom estimated would increase the impacts provided by the three UK PSBs by between 8.0% and 12.3% ((Ofcom, 2008, p74,76)). The second, "harmonizing down," would instead harmonize the treatment of PSBs and non-PSBs by restricting non-PSBs to advertise up to the PSB daily average of only 7 minutes per hour, the outcome of which Ofcom estimated would decrease the impacts provided by the non-PSBs, Sky and PSB Digitals, by approximately 6.9%.

Our results show that a policy harmonizing up would increase total PSB revenue by 10.5%, with increases at ITV1 of 10.6%, at C4 of 9.0%, and at Five of 13.8%. The policy is estimated to have a negligible long-run effect on Sky and the PSB Digitals, and that total industry revenue would increase by 6.7%. In contrast, we

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to better understand the demand for television advertising in the UK. See `http://stakeholders.ofcom.org.uk/market-data-research/tv-research/arr/` and `http://stakeholders.ofcom.org.uk/market-data-research/other/tv-research/econometric-analysis/` for further details. Note, however, that the conclusions in this paper differ from those in the reports. We discuss the reasons for these differences in Section E in the Appendix.

find harmonizing down would modestly increase total PSB revenue (by 2.6%, due mostly to an increase for ITV1 in response to decreased impacts at Sky), leave revenue for Sky unchanged, decrease significantly PSB Digitals' revenue (by 14.2%), and leave industry revenue unchanged. While we do not measure the consequences of increased advertising minutes on the television viewer experience or the effectiveness of advertising, we nonetheless conclude that permitting more PSB advertising minutes could increase PSB revenue in the face of increased competition from both multi-channel television providers and Internet media consumption.

Previous Literature. While there is a voluminous academic literature analyzing the impact of advertising on consumer behavior (Bagwell (2007)), there is surprisingly little empirical work analyzing the demand and supply of advertising *by advertisers*.[10] Goettler (2012) and Wildman et al. (2004) estimate reduced-form relationships of the responsiveness of advertising prices to audience size, but do not estimate the demand for audiences.

Bel and Domènech (2009) and Wilbur (2008) are important exceptions. Bel and Domènech (2009) relate advertising prices to advertising minutes and channel audiences in the Spanish television market, but do not account for the possible endogeneity of either variable or the presence of measurement error in prices and quantities. Wilbur (2008) models both sides of the television market (i.e. the demand for programming by households and the demand for audiences by advertisers) and estimates aggregate advertiser demand for those audiences. Care is also taken to account for potential endogeneity of viewership, advertising minutes, and/or advertising prices in estimation.[11] While the focus of Wilbur (2008) is limited to aggregate demand for advertising on U.S. broadcast television networks, the basic framework can be extended to allow for multiple channels, differentiated (PSB and non-PSB) broadcasters, and advertising limits of the kind used in the UK market. The modeling in this project is broadly based on the approach taken there.

The analyses closest in spirit to ours are those by Filistrucchi et al. (2012) and Zhang (2016). Filistrucchi et al. (2012) uses weekly impact and price data from TNS France for all major ad-supported French television channels between 2007 and 2009 to analyze the effects of a preliminary phase of the French ban on PSB

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[10]Older empirical work includes Hendry (1992), Masih (1999), and PriceWaterhouseCoopers (2004). Anderson and Jullien (2016) contains a summary of more recent theoretical work on advertising in two-sided markets while Berry and Waldfogel (2016) summarize the recent empirical work where quantity of advertising is a choice variable and not regulated by governnment agencies.

[11]We do not allow for possible feedback effects of increased advertising minutes on viewership by households, as an analysis prepared for Ofcom (Analysys Mason and BrandScience (2010); Analysys Mason (2011)) found the elasticity of consumer viewing to changes in advertising minutes to be sufficiently small that we are comfortable ignoring such effects.

advertising between 8:00 p.m. and 6:00 a.m. Their preliminary results complement our findings: gross advertising revenues for PSBs decline after the introduction of the ban, but much of the loss between 8:00 p.m. and 6:00 a.m. is recovered by increased PSB ad revenues between 6:00 a.m. and 8:00 p.m. Zhang (2016) also uses French data and studies the impact of removing ad minute regulations using data from 2014. She finds that removing the regulatory caps leads to the addition of one 30 second ad per 2 hours and has no significant effects on advertising prices. Her estimates suggest that deregulating advertising minutes would yield an additional 7.11 million Euros per channel per year in profits, equivalent to 0.7 % of broadcast costs for TF1, largest French PSB in terms of audience share, or 3.7% of broadcast costs for a M6 Group, a PSB of average size.

The paper proceeds as follows. In section 2, we describe the market for television advertising in the UK, paying particular attention to features of the market that influence the specification of our econometric model. In section 3, we introduce the OMG price data that permits the analysis. In section 4, we highlight the reasons for our choice of an inverse demand specification, introduce the reasons for and consequences of measurement error in our analysis, and present the econometric model and estimation methods we use in the analysis. Section 5 presents the results, section 6 presents our analysis of the likely revenue effects of changes in limits on advertising minutes, and section 7 concludes.

2. The UK Television Advertising Market

In this section, we describe how audiences are bought and sold in the UK television advertising market, including any constraints placed on the market by regulations mandated by Ofcom. These institutional details motivate our specification choices for the econometric model introduced in section 4.

Market Overview. Television markets are two-sided markets. Broadcast television stations and cable and satellite television systems provide a platform connecting households with program producers and advertisers. Households value the entertainment they get from watching television programs and are willing to pay for that entertainment. As they watch, they create audiences that, in turn, have value to advertisers. In pay-television markets, households "pay" for programming with both time (watching advertisements during and between programs) and money (monthly subscription fees).[12] In broadcast television markets, there are typically no subscription fees and households only pay with their

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[12]Examples of pay-television markets are the markets for cable and/or satellite subscription services offered by Sky Television in many Western European countries, including the UK, and television subscription services offered by the traditional telecommunication companies such as Vodafone TV, Virgin Media, and BT Vision.

willingness to watch ads.[13,14]

In the advertising market, advertisers demand audiences whilst broadcast and pay television channels supply them. Advertisers are typically firms who value audiences for the ability to inform and/or persuade them of the merits of their products or services.[15] Developing an advertising campaign strategy, designing the creative advertisements, and planning the actual purchases of advertising time, however, are specialized skills often not held by advertisers. As a result, they typically contract most or all of these elements of the advertising process to advertising agencies like GroupM, Omnicom Media Group, and Dentsu Aegis.[16]

Within a country, there are typically many individual broadcast and pay television channels.[17] Airtime on those channels are often sold on behalf of those channels by broadcasting sales houses.[18] Broadcast television channels can be divided into two groups: Public Service Broadcasters (PSBs) and non-PSBs. PSBs are required to provide programming that is in the public interest as a condition of their license; non-PSBs have no such restrictions. The primary PSBs in the UK are the BBC, ITV, Channel 4 (C4), and Channel 5 (Five). The BBC is principally funded by an annual television license fee and sells no advertising. The remaining PSBs have no license fees and are fully advertising-supported, as are all non-PSB channels in the broadcast television market.[19]

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[13]Broadcast television markets encapsulate all other television markets where content is (traditionally) distributed via radio waves and can be received by any household with an antenna. The key distinction between broadcast television and pay television is that households pay subscription fees to gain access to content under pay television whereas there are typically no fees to access broadcast television.

[14]In this paper, we focus only on the advertising side of the market. See Crawford and Yurukoglu (2012) and Crawford et al. (2016) for econometric analyses of both sides of the U.S. pay-television market.

[15]See Bagwell (2007) for the canonical survey of the economic analysis of advertising. Renault (2016) reviews the recent literature on the role of advertising in consumer decision making.

[16]There is often further specialization within agencies. For example, some advertising agencies specialize in designing the actual advertisements (so-called creative agencies) while others specialize in purchasing advertising time (so-called media buyers). For simplicity, we will refer to all such firms as ad agencies.

[17]Examples of broadcast television channels in the UK include the BBC One, ITV, Channel 4, and Five, all of which are PSBs, and channels such as Dave, E4, ITV2, and 5USA all of which are non-PSBs. Pay television channels in the UK include Sky Sports, Discovery Channel, Nickelodeon, and MTV (among many others).

[18]For example, in the UK, ITV owns four broadcast television channels: ITV1 (often just called ITV), and ITV2-ITV4. Time on all these channels (and related ITV properties) are all sold through ITV Media, ITV's sales house.

[19]The revenue model for pay television channels differs from that of broadcast television channels. As for broadcast channels, pay channels sell audiences and receive advertising revenues; unlike broadcast channels, they also negotiate "affiliate fees" from pay-television operators like Sky and Virgin Media who then charge households for access to these channels. In the US pay television market, these fees are typically set at a flat rate per subscriber and differ by channel and operator. See **?** for more discussion of these contracts in the US pay television context.

Impacts (Quantities) and Prices. In the UK television advertising market, audiences are measured in "impacts." An impact is one viewing of an advertisement by an individual television viewer. Since TV ads can be of different lengths (typically 10, 20, 30, or 60 seconds), broadcasters weight the impacts delivered for any individual ad to its thirty-second equivalent according to the value of that length relative to a 30-second ad.[20] Impacts may be differentiated by the demographic characteristics of the viewer and are measured in the UK by the Broadcasters' Audience Research Board (BARB), an audience measurement organization jointly owned by the major British producers of television programming. The price of an impact is typically expressed as a "cost per thousand (impacts)," or CPT.

When an advertiser decides to book a campaign, they consult with their ad agency to decide how many impacts are needed to get the desired effects. They agree on facets such as timing, channel mix, regional mix, and budget. The media buyer estimates the price to deliver the desired impacts by region, audience demographic, and month (as well as the total price). For any single region, demographic, month, and broadcast channel, there are two important factors that determine this price. The first is the station average price (SAP) of a television channel in the given month. The SAP is determined by the total revenue (across all demographics and time periods) of the channel in that month divided by the total impacts delivered in the desired demographic. The second is the discount (or premium) on the SAP due on the purchased impact.

While the discount or premium from SAP can vary by advertiser or even by ad, it is more typically given by the discount negotiated between the broadcast sales house and the media buyer.[21] This discount is typically set in annual contracts between media buyers and sales houses and is largely determined by two important factors. The first is the magnitude of the commitment by the media buyer to spend either a fixed share of the media buyer's total television advertising budget (aggregating across advertisers) and/or a volume guarantee, or both. The second is the "share of commercial impacts" (SOCI) delivered by a broadcast channel in the market. As larger audiences imply less duplication of advertising spending, advertisers are often willing to pay a premium for placing ads on those channels that have a larger share of the market. Like contracts between buyers and sales houses, SOCI is determined annually based on the performance of each channel in the previous calendar year.

The number of impacts supplied on a particular program depends on two things: the number of individuals that watch that program and, as discussed above, the number of advertising minutes on that program. The number of individuals that

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[20]These differ by broadcasters and are published as "commercial length rate factors." There were no changes to these factors over the period we study.

[21]Unlike in some media markets, advertisers in the UK purchase impacts from a broadcast sales house, but do not (generally) select the individual programs on which those ads are shown. The scheduling of ads across programs is itself done by the sales houses.

watch a program is determined by the attractiveness of the programming relative to other programs on at the same time and any non-television options.

An important and unusual institutional feature of the supply of programming in the UK in the period that we study is that both PSBs and non-PSBs had incentives to sell *all* their advertising minutes (and thus all their impacts) at all times. For PSBs, selling all their available airtime was a requirement of their PSB license.[22] Non-PSBs, on the other hand, had an incentive to maximize their impacts due to a remedy put in place at the time of the 2003 merger of Carlton and Granada (the two largest distributors of ITV) called Contract Rights Renewal (CRR). As described above, contracts between advertising agencies and broadcasting sales houses (like ITV's) often depend on the channel's SOCI. The terms agreed to under the CRR by the newly merged ITV ensured that any decrease in its SOCI would translate into a decreased discount on its SAP with buyers.[23] This gave non-PSBs an incentive to minimize ITV's SOCI by maximizing their own impacts. Figure 1 below demonstrates that, consistent with these arguments, both PSBs and non-PSBs in our data supplied the maximum number of advertising minutes that they were allowed.

Purchase Timing, "Balancing the Books," and Measurement Error. An important feature of the UK television advertising market is that purchase decisions are made by advertisers and their agencies several months in advance of the airing of the advertisements. Purchase decisions are therefore based on the impacts they *expect* to be achieved by given programs in the market at prices they *expect* to be realized. The actual impacts achieved and the actual price paid depend on the scheduling decisions of broadcast houses (and viewing decisions by consumers) and the actual SAP (less discount), which is itself determined at the end of the month in which the ads are aired. If there are deviations between expected and actual impacts and prices, these differences are reconciled in a process called "Balancing the Books."[24]

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[22]This rule was instituted in the 1990s to allay fears that ITV, the dominant PSB, would withhold airtime in an effort to increase their profit. In July, 2010, Ofcom withdrew this rule from the market effective September, 2010. See `http://stakeholders.ofcom.org.uk/consultations/asr/` for details.

[23]See `http://www.ofcom.org.uk/static/archive/itc/uploads/Basic_summary_of_the_Contracts_Right_Renewal_CRR_remedy.pdf` for more details about the workings of the CRR.

[24]A television sales house predicts its monthly SAP on the basis of its estimates of (advertiser) expenditure commitments and consumer audience levels. The sales house then places booked advertisements on a selection of spots in order to achieve the required number of impacts to fulfil the advertiser's deal. If the sales house does not achieve sufficient impacts to fulfil the deal, in effect the advertiser is paying a higher price per impact than agreed, and the sales house has overtraded (or underdelivered). This results in the sales house having to give the advertiser extra impacts in a future month. In practice deal debt situations such as these do not occur very frequently, as a broadcaster monitoring its deals during the month takes action before the month's end. For example, if a sales house is expecting to have overtraded (underdelivered) towards the

In our econometric model, we allow for measurement error due to differences in expected and realized prices and impacts induced by the timing of purchase decisions in the UK advertising market. We note, however, that based on industry sources, the magnitudes of any such measurement errors are likely to be small. Following discussions with industry experts, we understand that, on average, actual deviations between expected and actual commercial impacts and prices are generally between 0 and 3%.[25] In addition, the 2010 decision from the UK Competition Commission (CC) on CRR described in detail the relevant process and found that broadcasting sales houses continually optimize their placement of ads to ensure that over- and underdelivery does not frequently occur.[26]

3. Data

We use a unique dataset to evaluate the inverse demand for UK television audiences in this paper. The data were provided by Omnicom Media Group (OMG) and consist of monthly data on impacts and revenues (from which we construct prices) across the spectrum of UK television channels, as well as additional factors that might influence the demand for audiences.[27]

PSB and Non-PSB Channels. We focus our analysis on the main PSB and non-PSB channels from January, 2002 until July, 2009.[28] For PSBs, these are ITV1, C4, and Five.[29] In addition to these "flagship" channels each of the PSBs have introduced

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end of the month, any company wishing to advertise at short notice will be charged a high premium as the opportunity cost of those impacts is high. Likewise, if the sales house has undersold (overdelivered), it will sometimes offer late bookings at a lower price as the oppportunity cost of those impacts is low.

[25]It is inherently difficult to measure these deviations exactly since buyers of advertising constantly update their beliefs about future expected prices and impacts, the records for which are not generally kept.

[26]See Competition Commission (May 2010) Review of ITV's Contracts Rights Renewal Undertakings, Sections 2.28 to 2.31 and footnote 41, available at: http://www.competitioncommission.org.uk/rep_pub/reports/2010/557ITV.htm

[27]These data were provided under strict non-disclosure and security restrictions exclusively for the purpose of this analysis.

[28]We intended to analyze data from January 2000 onwards. However, two data reliability issues led us to restrict our analysis to begin in 2002. First, we are not confident of the accuracy of the data on Sky impacts which were gathered during 2000 and 2001. In addition to this, and perhaps more importantly, 2002 saw the introduction of a new BARB panel. Some problems in the new panel were well documented at the time, but what was not publicised was the condition of the old panel towards the end of the contract. That panel became worryingly imbalanced, which led to overt pressure on weighting structures. We therefore feel more confident about measurement and demographic data from 2002 onwards. We end in July, 2009, as that was the latest month available when we originally obtained the data.

[29]We have combined C4 and S4C - which replaces Channel 4 across Wales - together because of S4C's close relationship with C4. We do not include a final PSB, GMTV, as it is a relatively small

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additional "portfolio" channels over the last 15 years. For example, ITV owns ITV2, ITV3, and ITV4 in addition to its flagship channel, ITV1. We intended to evaluate each of these portfolio channel families (e.g., the ITV family consisting of ITV2-4) separately, but our data isn't as rich for them as for the other channels: doing so yielded insignificant effects for these channels in nearly all equations (including their own). Instead, we have aggregated all portfolio channels into a "PSB digital" channel family and include that as a fifth "channel."[30]

For non-PSB channels, we intended to evaluate the main non-PSB families (such as Sky) on an individual basis. However, the data available for the Sky sales house includes revenues from several third-party channels such as the Discovery Channel and Nickelodeon, which are sold via Sky's platform. As it is not possible to gather sufficiently disaggregated data which would allow us to separate out the third-party channels from Sky's own channels, we had to combine all non-PSB channels that are not part of the ITV1, C4 or Five families into a single channel grouping, denoted "Sky".

Advertising Minutes. In Section 2 we described how the idiosyncratic nature of industry regulations and conditions on a 2003 merger in the UK advertising market ensure that both PSB and non-PSB channels sell all the advertising minutes they are permitted to sell. Figure 1 reports, for each of the three PSB channels and a representative sampling of non-PSB channels, the average number of advertising minutes sold per day over the course of our sample, Over the sample period PSBs (non-PSBs) were permitted an average of 168 minutes per day, 7 minutes per hour, and non-PSBs were permitted 216 minuted per day, 9 minutes per hour.[31] The figure demonstrates that these caps were effectively binding throughout the entire sample period. Because of this, all variation in monthly impacts within and across channels of the same (PSB/non-PSB) type arises due to differences in viewing within and across those channels rather than differences in the number of advertising minutes within or across channels.

Channel-Specific Advertising Revenue, Prices, and Impacts. Our study utilises monthly revenue data accumulated and maintained by OMG, split out by major channels

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player in the market. We note that our estimates of "Total PSB" and " Total Industry" variables (e.g., impacts or revenue) could therefore be slightly less than those reported in other industry sources.

[30]This is imperfect as it is likely that prices for, e.g., the ITV digital family would respond differently to changes in (the flagship) ITV's impacts than they would to changes in C4's impacts. Despite this weakness, we thought it preferable to include them under this restriction than to drop them entirely from the analysis. All of our qualitative results are similar whether we split them out and aggregate them, aggregate them with each one's parent channel, or drop them from the analysis.

[31]In addition to the daily average minute averages, channels were limited to providing a maximum of 12 minutes of advertising in any one hour of the day.

Figure 1: Daily number of broadcast advertising minutes by channel
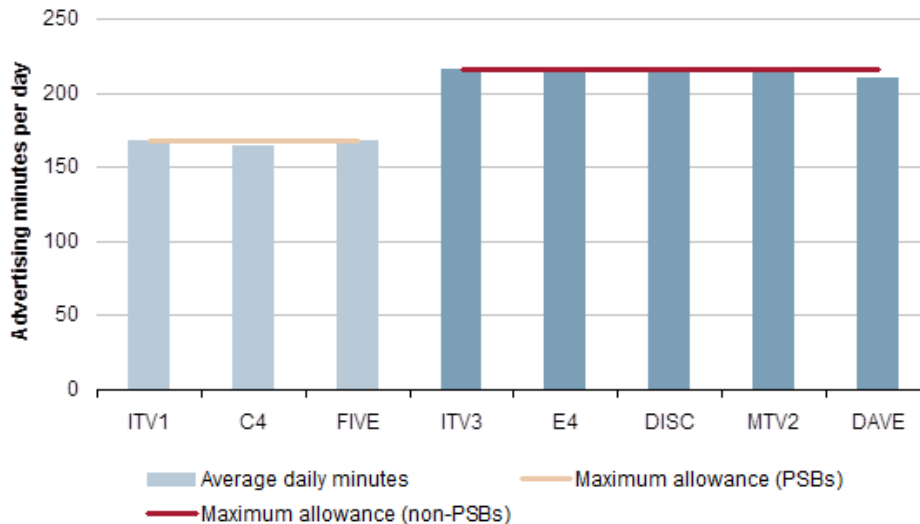
Notes: Reported are the average number of broadcast advertising minutes for a selection of PSB and non-PSB television channels. The maximum allowable minutes of advertising per day for PSBs is 168 minutes and for non-PSBs i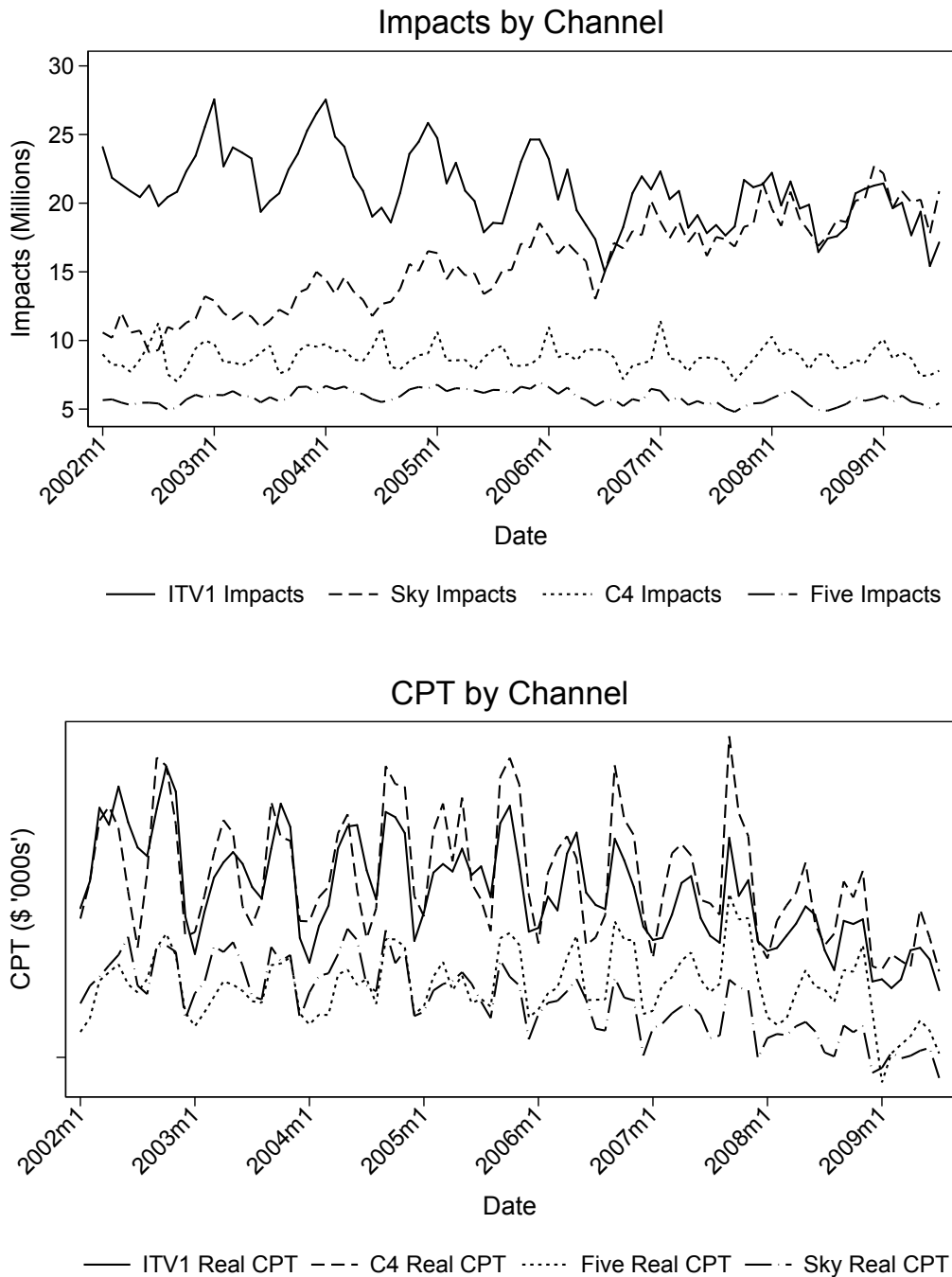s 216 minutes. The average is taken across all the days in our sample period, January 2002-July 2009. Source: Analysys Mason and BrandScience (2010).

and sales houses. Following industry practice, we construct monthly prices by channel, CPT, for our viewing demographic (all adults) by dividing the channel's monthly revenue by the number of impacts delivered by those adults. We deflated the data using a headline measure of inflation (RPIX) so that all prices are expressed in real 2002 GBP.

Within the advertising market, impacts for a specific advertising campaign are measured and sold against a target demographic group. As such, demographics are a key component in determining prices within the advertising market. We note that the share of impacts delivered by demographic for all channels are almost constant over time, hence we use impacts and prices for all adult viewers to a channel and do not distinguish between the component demographics delivered.

Figure 2 reports impacts (for all adult viewers) and prices (CPT) for each of the main channels used in our analysis. For confidentiality reasons, we do not report the level of prices in the lower panel. There is a clear cyclicality to the data (viewing and thus impacts are highest in winter months) as well as secular trends, common to television markets around the world. Among PSB impacts, all impact losses over the period are at ITV (-10.1%), while C4 (+1.0%) and Five (+1.2%) are effectively unchanged. Sky impacts are up significantly (+77.0%). CPT has fallen over the period for all channels, between -35.4% for Sky, -31.7% for ITV and -6.1%

Figure 2: Impacts and prices over time for the PSB channels and Sky

Impacts by Channel

Legend: ITV1 Impacts — Sky Impacts - - - C4 Impacts ······ Five Impacts — · —

CPT by Channel

Legend: ITV1 Real CPT — C4 Real CPT - - - Five Real CPT ······ Sky Real CPT — · —

Notes: Reported are the impacts and prices (costs-per-thousand) for each of the PSB channels and the Sky group of channels. As discussed early in Section 3, the Sky group of channels includes all the channels owned by Sky as well as all non-PSB channels not belonging to Sky or the sales houses of the PSB channels. For confidentiality reasons, we do not report the level of prices in the bottom panel.

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for Five.

We also include in our model three other important variables. These are a channel's share of commercial impacts (SOCI), the number of internet impressions, measuring the demand for a growing substitute for television advertising, and the value of the FTSE 100, measuring the income or wealth of the firms that demand audiences from broadcasters.

4. Econometric Model

4.1 Overview

In this section, we outline our econometric model of the demand for advertising in the UK television market. We begin by motivating why we choose to estimate indirect demand equations rather than direct demand equations. We then discuss the likelihood and consequences of measurement error in our key variables, impacts and prices, and outline our instrumental variables procedure.

4.2 Inverse versus direct demand

We specify inverse demand equations for each of the PSB (ITV, C4, Five) and non-PSB (Sky, PSB Digitals) television channels that relate the price of advertising on a given channel to the quantity of impacts offered by all channels. We choose to specify inverse demand equations rather than direct demand equations because it better reflects the nature of equilibrium in television markets: channels "bring to market" a given number of impressions each month and the price of those impressions adjusts to balance demand and supply. Inverse demand equations are widely used in the analysis of markets for agricultural products and natural resources in which prices rather than quantities are used to equate demand and supply.[32]

As outlined in Section 2, PSBs and non-PSBs in the UK market offer all the advertising minutes they can under the existing regulatory framework. In this institutional environment, price is the only equilibrium adjustment mechanism available. Because advertising impacts are the product of viewers and advertising minutes, this means that the supply of impacts is perfectly inelastic in a given month. Even if advertising prices are very high in a given month, there is nothing that a television channel can do to provide more impacts.

The primary consequence of estimating inverse demand equations instead of direct demand equations is that one estimates a demand *flexibility*, define as "the

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[32]See, e.g., Park and Thurman (1999), Holt (2002) and the references cited there.

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percentage change in the price of a commodity associated with a 1 percent increase in the quantity demanded of that commodity ..., all else remaining constant" (Houck (1965)), rather than the more familar demand elasticity. In a single-product setting, the elasticity of demand is simply given by the inverse of the flexibility.[33] In a multi-product setting this relationship is more subtle: elasticities hold other prices fixed while flexibilities do so for other quantities, which destroys the simple inverse relationship.

Fortunately, these differences are immaterial if one is primarily interested in predicting the revenue consequences of a change in advertising minutes as we are in this paper. Much as revenue decreases with price (and increases with quantity) if demand is elastic (i.e. $|\partial \log(q_j)/\partial \log(p_j)| > 1$), revenue increases with quantity (and decrease with price) if demand is *in*flexible (i.e. $|\partial \log(p_j)/\partial \log(q_j)| < 1$) Eales and Unnevehr (1994).[34] In what follows below, we focus on these revenue effects in the interpretation of our flexibility results.

4.3   Expected impacts, expected prices, and measurement error

In Section 2 above, we described how purchases of advertising time are made several months in advance of the actual airing of the ads and how they are based on judgements by market advertisers and/or media buyers about the expected impacts and expected price of impacts in that month. This means we would like to regress expected (log) prices in period t, p_t^*, on expected (log) impacts in this period, q_t^*:

$$p_t^* = \alpha + \beta q_t^* + \epsilon_t^* \tag{1}$$

However, we are not able to observe these expected prices and impacts. We observe realized prices and impacts, which can be represented as the expected value plus a measurement error:

$$
\begin{aligned}
p_t &= p_t^* + \rho_t \\
q_t &= q_t^* + \eta_t
\end{aligned}
\tag{2}
$$

Recall that observed prices are given by revenues divided by impacts. Thus the error in observed prices, ρ_t, could originate either from deviations in revenues from expectations or deviations in impacts from expectations. In the latter case, impacts greater than that expected may reasonably yield prices lower than expected, or $Cov(\rho_t, \eta_t) < 0$ implying $Cov(\rho_t, q_t) < 0$.

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[33]The same is not true, however, for a mapping of estimated flexibilities into estimated elasticities: Huang (2005) shows that the *estimated* own-price elasticity will be less elastic than that implied by the inverse of the estimated own-price flexibility because the projection of a variable Y on a variable X (as in OLS) is not the inverse of a projection of X on Y.

[34]Thus the reader should associate the revenue effects of inflexible inverse demand with those of elastic demand (and similarly flexible inverse demand with inelastic demand).

Substituting and rewriting equation (1) yields:

$$p_t = \alpha + \beta q_t + (\epsilon_t^* + \rho_t - \beta \eta_t)$$
$$= \alpha + \beta q_t + \epsilon_t \qquad (3)$$

where $\epsilon_t = \epsilon_t^* + \rho_t - \beta \eta_t$.

In the presence of measurement error in prices and impacts, there are three sources of error underlying an inverse demand equation: shocks to expected demand in period t, ϵ_t^*, measurement error in prices, ρ_t, and measurement error in impacts, $-\beta \eta_t$. Both of the latter two are problematic for OLS regression as both are correlated with q_t. Positive shocks to impacts ($\eta_t > 0$) increase observed impacts, $q_t > q_t^*$, and are (1) negatively correlated with measurement error in prices, $\rho_t < 0$, and (2) positively correlated with $-\beta \eta_t$ - the attenuation bias common with measurement error problems. Which of these potential biases is stronger, and thus the direction of bias in an OLS estimator, is unknown ex-ante. In what follows, we outline an IV estimation strategy that serves to address these concerns.

4.4   A inverse demand system for advertising on UK television channels

We now outline our econometric model and estimating procedure. Let t index months and let j index the television channels included in the analysis, $j = \{1, 2, 3, 4, 5\}$, with $j = 1$ for ITV1, $j = 2$ for C4, $j = 3$ for Five, $j = 4$ for Sky, and $j = 5$ for the PSB Digitals. A static inverse demand equation in logs is then, for each of $j = 1, ..., 5$:

$$\log p_{jt} = \alpha + \beta_{j1} \log q_{1t} + \beta_{j2} \log q_{2t} + \beta_{j3} \log q_{3t} + \beta_{j4} \log q_{4t} + \beta_{j5} \log q_{5t}$$
$$+ \beta_{j6} \log SOCI_{jt} + X_{jt}' \gamma_j + \epsilon_{jt} \qquad (4)$$

where p_{jt} is the price (CPT) of channel j in month t, q_{jt} measures its impacts, $SOCI_{jt}$ is its share of commercial impacts (SOCI) for the calendar year previous to the one containing month t, X_t are other inverse demand shifters whose effects on price are captured by γ_j, and $\epsilon_{jt} \equiv \epsilon_{jt}^* + \rho_{jt} - \sum_{k=1}^5 \beta_{jk} \eta_{kt}$ consists of shocks to advertisers' expected inverse demand in period t as well as measurement error in both p_{jt} and each of the q_{jt}'s. In each equation, we require instruments that are correlated with each q_{jt} and uncorrelated with the composite error, ϵ_{jt} to solve the measurement error bias inherent in OLS.

We consider monthly time lags for commercial impacts to be suitable instruments. Advertisers as well as broadcasters use past values of impacts to predict future expected impacts. In particular, trends over the previous months and year(s) are likely to be key factors in estimating the future supply of commercial

impacts. Lags of impacts, q_{jt-k}, are therefore likely to be correlated with contemporaneous impacts, q_{jt}.

We also believe that these lags are not likely to be correlated with any of the components of the error term, ϵ_{jt}. The measurement error in commercial impacts for a specific month is caused by the (incorrectly estimated) relative attractiveness of programs compared to other programs, or other factors such as sudden weather shocks that influence the overall attractiveness of watching television. In our view, it is highly unlikely that there is a correlation of errors in a particular month, t, with lagged commercial impacts from previous months. The only case where this assumption would be violated would be if there was serial correlation in the measurement errors, η_{jt} and ρ_{jt}. However, as advertisers and broadcasters closely track market developments over time, any unexpected supply shock in the past will trigger an adjustment of expectations and should not lead to a correlated shock (positive or negative) in an upcoming month.

5. Estimation and Results

5.1 Diagnostic Tests, Final Model Specification, and Estimation

In the course of our econometric analysis, we considered alternative specifications of the baseline model specified in equation (4) above that accommodate dynamic behavior. Dynamics are to be expected in this market for some of the same reasons discussed earlier. In particular, since advertising purchase decisions are typically made several months prior to outcomes being realized in the market, it would not be surprising for prices and/or impacts lagged several months to influence behavior in a given month t. Similarly, there are strong annual effects in the data, suggesting behavior 12 and/or 24 months previous to a given month may also influence behavior.

We analyzed the data for evidence of such dynamic effects in the implementation of our econometric estimation. We began by exploring alternative distributed lag structures. A model with a one-month lag of a channel's own price was found to be the best specification. We found no strongly significant effects on our overall conclusions when including more lags of price or including lag impacts. Futhermore, adding additional variables did not add further explanatory power or improve performance in any of our diagnostic tests.

We next considered the specific functional form to select.[35] To facilitate this decision, on an equation-by-equation basis we implemented the PE test of the linear

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[35]Much like AIDS demand systems are a common choice of functional form in the estimation of direct demand systems, indirect AIDS (or IAIDS) systems are sometimes chosen for the estimation of indirect demand systems, particularly in the agricultural economics literature (e.g. Holt (2002)). We considered this possibility, but decided a linear or log-log system captured all the aspects we were interested in and was easier to implement.

versus log-log model (Davidson and MacKinnon (2004)). There was not a consistent model preferred across equations.[36] We also estimated a Box-Cox model with a single shape parameter for each of the price and five impact variables. While there were still differences across equations, the shape parameter across equations tended to favour the log-log specification.[37] The final econometric model we chose was therefore a log-log model. For $j = 1, \ldots, 5$, this was given by:

$$
\log p_{jt} = \alpha + \kappa_j^1 \log(p_{j,t-1}) + \left[\sum_{k=1}^{5} \beta_{jk} \log q_{k,t} \right]
$$
$$
+ \beta_{6j} \log SOCI_{jt} + X_{jt}' \gamma_j + \epsilon_{jt} \tag{5}
$$

We estimate the model using single-equation OLS and Instrumental Variables (IV) estimation techniques.[38] For OLS estimations we use Newey-West standard errors, with a three-lag autocorrelation structure for the residuals. In the IV regressions, we used a Bartlett Kernel with a three-lag autocorrelation structure and calculated the standard errors of the two-step GMM procedure so that they are robust to heteroskedasticity and autocorrelation (HAC).[39] Changes in the specified lag structure were not found to influence our results. For the instrumental variables estimation, each equation has five right-hand-side endogenous variables (the impacts for each channel). We began with a common set of instruments for each variable in all equations and then customized this specification based on diagnostic tests including the first-stage F statistic measuring the significance of the instruments, the Hansen J test of overidentifying restrictions, and the Hausman-Durbin-Wu (HDW) endogeneity test of the included (potentially) endogenous impacts.[40]

While the outcomes of these tests varied across equations, some patterns emerged. As a general rule, the lagged impacts for each channel were the most powerful instruments for the current impacts of that channel. Furthermore, the first lag appeared quite often to be a good instrument, the twelfth lag appeared frequently to be a good instrument, and the second lag occasionally appeared to be a good

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[36]The linear model was preferred in two cases and the log-log model in three. While we could have implemented different functional forms, we preferred to have a consistent econometric specification across the equations.

[37]Across all specifications (linear, log-log, and Box-Cox), there were few qualitative differences in the matrix of own- and cross-product flexibilities implied by the estimates.

[38]Estimating using system methods like SUR and GMM would be more efficient if all equations were correctly specified, but raises the possibility of inconsistency in all equations if even one equation is mis-specified. We choose to be conservative and use single-equation methods.

[39]For the autocorrelation structure we use a Bartlett Kernel with a maximum lag order of 3. Our OLS results with Newey-West Standard Errors also use a maximum lag order of three.

[40]Our baseline set of instruments were the one-, two-, three- and twelve-monthly lags of impacts for all five channels, amounting to 20 potential instruments per equation.

instrument. The final instruments selected for each equation are specified in Appendix Table C. The first-stage F-statistics, HDW, and Hansen J tests for each equation are reported at the bottom of Table 2.

5.2 Results

Tables 1 and 2 report the OLS and IV estimates respectively for the key parameters in each of our five inverse demand equations.

Short-run Flexibilities. We begin our discussion with the matrix of short-run flexibilities given by the top five rows in Tables 1 and 2. The kj^{th} element reports the short-run flexibility of the channel in column j with respect to channel in row k, e.g. the 3rd element in the first row of the IV results, 0.67, represents the cross-flexibility of the price (CPT) of Five with respect to impacts of ITV1. It implies a 10% increase in the number of ITV1 impacts would be associated in the short run with a 6.7% rise in the price Five could expect to receive, controlling for the impacts of the other channels in the market. Of particular interest are the own-impact flexibilities, given by the diagonal (jj^{th}) elements in each set of results.

In the OLS and IV specifications, for all channels, the short-run own-impact flexibilities of each set of results are estimated to be *inflexible*. Estimates in the OLS results range from -0.34 for the Digital PSB channels to -0.84 for Five. Short run flexibilites arising from the IV estimations range from -0.06 for the PSB digitals through to -0.81 for Five. Estimates of short-run own-impact flexibilities are statistically different from zero except for the IV point estimate for the PSB digitals. Interpreting these own-impact flexibilities for the PSBs suggests a 10% increase in the number of a channel's own impacts would decrease prices by 7.5% for ITV, 6.8 % for C4 and 8.1% for Channel 5, holding all other market impacts fixed. As discussed in section 4.2, inflexible inverse demand predicts that (here, short-run) revenue would increase in response to an increase in the impacts provided by each channel on the market.

The short run in our setting is defined to be immediate, i.e. within an individual month. There are two mechanisms in the market that may yield different effects in the long run. The first is the time it takes for market developments to filter into the outcomes of decisions made by participants in the market. We described earlier how decisions by market participants about advertising plans take several months to be implemented and captured these dynamic effects by including, in each inverse demand equation, lagged prices. The second is the impact changes in the economic environment may have on a channel's share of (industry) commercial impacts (SOCI). Industry experts report that SOCI influence prices paid by advertisers to channels, and as discussed in Section 2 is determined on an annual basis using the previous year's total impacts. The long run in our setting

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Table 1: OLS Estimates of Inverse Demand Curves for Advertising.

	Log CPT ITV1	Log CPT C4	Log CPT Five	Log CPT Sky	Log CPT PSB Dig.
Short-run Flexibilities					
(Log Impacts$_t$)					
ITV1	−0.68	0.01	0.07	−0.02	−0.53
	(0.26)**	(0.11)	(0.18)	(0.11)	(0.23)**
C4	0.14	−0.81	0.21	−0.04	−0.09
	(0.09)	(0.11)***	(0.13)	(0.08)	(0.12)
Five	0.06	0.14	−0.84	0.14	0.24
	(0.20)	(0.12)	(0.20)***	(0.10)	(0.25)
Sky	−0.04	0.28	0.12	−0.68	0.59
	(0.19)	(0.25)	(0.29)	(0.25)***	(0.34)*
PSB Dig.	0.04	−0.01	0.04	−0.03	−0.34
	(0.05)	(0.04)	(0.08)	(0.06)	(0.07)**
Other Parameters					
Log CPT$_{t-1}$	0.20	0.29	0.20	0.56	0.37
	(0.09)**	(0.09)***	(0.12)	(0.14)***	(0.13)***
Log SOCI$_t$	0.76	0.40	0.31	0.32	0.03
	(0.43)*	(0.42)	(0.31)	(0.60)	(0.10)
Log Internet Impacts$_t$	−0.14	−0.18	−0.23	0.00	0.05
	(0.08)*	(0.05)***	(0.09)**	(0.07)	(0.10)
Log FTSE$_t$	0.21	0.28	0.42	0.15	0.52
	(0.06)***	(0.08)***	(0.17)**	(0.06)*	(0.11)***
Spec. Test (p-value)					
BG Autocorr.	0.07	0.16	0.24	0.59	0.08
White's Heterosk.	0.45	0.45	0.45	0.45	0.45
PE Test	0.69	0.75	0.00	0.00	0.59

Notes: Newey-West Standard Errors in paranetheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Month dummies and a constant also included but not reported. Test statistics reported for each equation include the p-values for the Breusch-Godfrey test for serial correlation of maximum order 3 in the residuals, the White test for heteroscedasticity, and the PE test for log-log versus linear functional form. Note that the top panel provides estimates of the short-run flexibilities. See Section 4.2 and Table 3 for more detail.

Table 2: IV Estimates of Inverse Demand Curves for Advertising.

	Log CPT ITV1	Log CPT C4	Log CPT Five	Log CPT Sky	Log CPT PSB Dig.
Short-run Flexibilities (Log Impacts$_t$)					
ITV1	−0.75	0.54	0.67	0.18	−0.04
	(0.28)***	(0.20)***	(0.44)	(0.13)	(0.28)
C4	0.33	−0.68	0.15	−0.21	−0.14
	(0.12)***	(0.10)***	(0.25)	(0.13)	(0.21)
Five	0.36	0.30	−0.81	0.31	−0.28
	(0.26)	(0.15)**	(0.45)*	(0.14)**	(0.40)
Sky	−0.35	−0.12	0.09	−0.53	0.95
	(0.32)	(0.32)	(0.49)	(0.26)**	(0.39)**
PSB Dig.	−0.04	−0.01	0.13	−0.01	−0.04
	(0.08)	(0.06)	(0.10)	(0.08)	(0.11)
Other Parameters					
Log CPT$_{t-1}$	0.22	0.30	0.23	0.57	0.23
	(0.09)**	(0.07)***	(0.10)**	(0.10)***	(0.09)***
Log SOCI$_t$	0.11	−0.19	0.57	0.30	−0.25
	(0.43)	(0.40)	(0.38)	(0.55)	(0.17)
Log Internet Impacts$_t$	−0.09	−0.06	−0.19	−0.02	−0.08
	(0.07)	(0.09)	(0.11)	(0.05)	(0.10)
Log FTSE$_t$	0.25	0.35	0.34	0.15	0.41
	(0.05)***	(0.06)***	(0.17)**	(0.06)**	(0.10)***
First Stage F-stat.					
ITV Impacts	6.86	3.46	3.75	6.35	3.01
C4 Impacts	5.37	6.09	4.04	2.69	6.06
Five Impacts	9.98	8.77	7.71	9.49	11.10
Sky Impacts	6.11	5.87	9.24	5.03	5.86
PSB Dig. Impacts	23.89	13.37	22.72	11.39	22.42
Spec. Test (p-value)					
Hausman-Durbin-Wu	0.42	0.28	0.92	0.21	0.24
Hansen J-test	0.28	0.54	0.18	0.28	0.25

Notes: Heteroskedasticity and Autocorrelation Consistent Standard Errors in paranetheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Month dummies and a constant also included but not reported. For each equation we report the F-statistics for each first stage regression of the five endogenous variables (each channel's log impacts). Instruments included in the final regression specifications are detailed in Appendix Table C. Test statistics reported for each equation include the p-values for the Hausman-Durbin-Wu endogeneity test and the Hansen J-test of the overidentification conditions. Note that the top panel provides estimates of the short-run flexibilities. See Section 4.2 and Table 3 for more detail.

is therefore between one and several years. We describe the long-run flexibilities implied by our IV results, which are our preferred estimates, after further discussing the parameters and specification tests in Tables 1 and 2.

Other Parameters and Specification Tests. The remaining parameters in Table 2 largely accord with intuition. Lagged prices appear to be statistically and economically important determinants of existing prices for all channels. Also as expected, internet impacts are generally associated with lower prices for television impacts and a generally better corporate economic environment, as measured by the FTSE 100 stock market index, is generally associated with higher advertising prices. Across all specifications we cannot identify a strong association between a channel's SOCI and own prices. This stands in contrast to industry expectations and descriptions of price setting behaviour which had emphasized a positive association between SOCI and prices.[41]

Tests for serial correlation (using the Breusch-Godfrey test), heteroscedasticity (using the White test), and linear versus log-log functional form (using the PE test) While some there is some evidence of serial correlation in both the ITV1 and PSB-Digitals equations, additional lags of the dependent variables or lags of explanatory variables made little difference to the test statistic and produced qualitatively and quantitatively similar results to those reported in the table. Although the PE test indicates linear functional form may be preferred over the log-log specification for the Five and Sky inverse demand curves, we keep the log-log specification so that functional forms are consistent across equations.

Tests regarding instrument validity are reported at the bottom of Table 2. While the first stage F-statistics are below the 'rule-of-thumb' level of 10 (Stock et al., 2002), this 'rule' does not apply to environments with autocorrelation like that we analyze here.[42] The final set of instruments used in each regression specification gave us the best possible results in terms of instrument strength. Although

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[41]One possible explanation for this is that over our short sample period each channel's SOCI does not move by a large enough amount for the regression specification to precisely estimate the impact of SOCI over and above contemporaneous impacts. An alternative explanation is that after accounting for contemporaneous impacts there is no relationship between prices and SOCI, and industry wisdom of the positive association is actually picking up the relationship between prices and contemporaneous impacts, which are highly correlated with SOCI over time. We decided to keep SOCI in our final regression specificiations because we believe the cost of including a potentially irrelevant variable (larger standard errors) is smaller than the cost of omitting a relevant variable, and the resulting omitted variable bias. Omitting the SOCI variable from the regression specifications and re-computing the counterfactual results has no qualitative impact on the results we document below, but does tightens the standard errors on long-run flexabilites and counterfactual predictions.

[42]Recent theoretical work by Olea and Pflueger (2013) and Moreira and Moreira (2015) investigates testing for weak instruments in the presence of heteroskedasticity and autocorrelation. However, their results are derived conditional on the presence of only one endogenous variable, whereas our setup features five endogenous variables.

the Hausman-Durbin-Wu statistics indicate that endogeneity may not be a major concern, we prefer the IV regression results because the market environment described in Section 2 indicates the presence of (small) measurement errors are an institutional feature of the UK television advertising marketplace.

Long-run Flexibilities. Table 3 reports the long-run flexibilities associated with both the OLS and our preferred IV estimates. They are given by the following formula, derived in Appendix D:

$$\frac{\partial \log p_{jt}^{LR}}{\partial \log q_{kt}} = \begin{cases} \frac{\beta_{jk} + \beta_{6j}(1 - SOCI_{jt})}{1 - \kappa_j^1} & \text{if } k = j \\ \frac{\beta_{jk} - \beta_{6j} SOCI_{kt}}{1 - \kappa_j^1} & \text{if } k \neq j \end{cases} \tag{6}$$

These long-run flexibilities include the indirect effect on flexibilities of the SOCI, captured by the second term in each numerator. They also differ from the short-run flexibilities by taking into account pricing dynamics which were modelled though including lagged own price in the regression specification. The presence of SOCI in the long-run flexibility (under the assumption $\beta_{6j} > 0$) makes long run demand more flexible than its short-run counterpart. These larger (in absolute value) flexibilities mean smaller long-run revenue effects, impling that changes in impacts that are profitable in the short-run may be less profitable after long run adjustments. In addition, the inclusion of lagged price as a regressor means that (holding fixed the SOCI coefficient) long-run flexibilities are larger in absolute value than the short-run estimates. This effect reinforces that profits in the long run may be less responsive to changes in impacts than in the short run.

The estimates reported in Table 3 show that, with one exception, demand is generally estimated to be inflexible.[43] The exception is Channel 4, which has long-run demand with a own-flexibility point estimate of -1.21.[44] Comparing long-run own-flexibilities to their short-run counterparts we see that long run flexibilities are generally larger in absolute magnitude - i.e that long-run demand is more flexible than short-run demand. When demand is less inflexible in the long-run

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[43]We note that the standard errors of the estimated long-run flexibilities are relatively large. This can mostly be attributed to including the SOCI in the regression specification - which was estimated imprecisely in the regression results in Table 2.

[44]Recall that, for a single demand curve, the revenue effect of inflexible demand is like that for elastic demand in that an increase in price (equivalently a decrease in quantity) lowers aggregate revenue whereas the revenue effect of flexible demand is like that for inelastic demand in that an increase in price (equivalently a decrease in quantity) increases aggregate revenue. Effects in our model are more complicated due to the interaction of demand across the five channels/channel groups. The counterfactual exercises conducted in Section 6 account for all the own- and cross-channel effects to measure the revenue consequences of changes in aggregate impacts for each channel and/or channel group.

Table 3: Long Run Demand Flexibilities - OLS and IV Estimates.

| | OLS | | | | | IV | | | | |
	ITV1	C4	Five	Sky	PSB Dig.	ITV1	C4	Five	Sky	PSB Dig.
ITV1	−0.25	−0.20	−0.05	−0.32	−0.85	−0.87	0.87	0.60	0.17	0.08
	(0.50)	(0.30)	(0.27)	(0.51)	(0.34)	(0.65)	(0.44)	(0.43)	(0.52)	(0.46)
C4	0.03	−0.65	0.21	−0.21	−0.15	0.41	−1.21	0.08	−0.59	−0.15
	(0.14)	(0.47)	(0.18)	(0.25)	(0.19)	(0.16)	(0.47)	(0.29)	(0.34)	(0.31)
Five	−0.02	0.14	−0.71	0.25	0.37	0.44	0.46	−0.39	0.66	−0.37
	(0.29)	(0.18)	(0.29)	(0.20)	(0.39)	(0.38)	(0.24)	(0.33)	(0.29)	(0.57)
Sky	−0.31	0.24	0.04	−1.00	0.92	−0.49	−0.09	−0.09	−0.74	1.51
	(0.23)	(0.29)	(0.35)	(0.75)	(0.57)	(0.33)	(0.38)	(0.56)	(0.74)	(0.62)
PSB Dig.	−0.04	−0.07	0.01	−0.15	−0.49	−0.06	0.01	0.10	−0.09	−0.40
	(0.06)	(0.07)	(0.09)	(0.26)	(0.12)	(0.08)	(0.10)	(0.12)	(0.29)	(0.12)

Notes: Reported are the estimated long-run flexibilities (the percentage change in price associated with a percentage increase in quantity) implied by the OLS and IV estimates reported in Table 1 and Table 2. See Section 4.2 for a discussion of flexibilities and their relationship with elasticities. Flexibilities less than one in absolute value are called "inflexible" and imply that prices fall by proportionally less than quantities increase, yielding revenue increases (controlling for the impact on other channels' prices). The long-run flexibilities presented here account for the dynamic price responses induced by the lag price terms in each equation as well as the influence of any quantity increase on that channel's SOCI. See Equation (6) in the text. Standard errors, in parentheses, are calculated by the delta method based on the variance-covariance matrix of the estimates from Table 1 and Table 2 repsectively.

compared to its short-run equivalent, holding other impacts fixed, long-run profit changes from an expansion in own impacts are smaller than in the short-run.

The cross-flexibilities between channel pairs play an important role in our counterfactuals presented in the next section and therefore deserve some discussion. Cross-flexibilities between each of the PSBs (ITV, C4 and Five) are estimated to be *positive*. This suggests that most channel pairs are *complements:* increases in the impacts provided by Five cause a decrease in the price of ITV's impacts as advertisers shift their spending from ITV to Five, lowering ITV's demand. This is not necessarily surprising: if advertisers have fixed budgets, a decrease in the price of one channel's impacts yields not only increased purchases of advertising time on that channel, but might also free up budget to purchase time on other channels as well.[45]

Differences between OLS and IV results. There are modest but substantively important differences between our estimation results using OLS versus IV. Focusing on the own-impact flexibilities, we see that the IV results are (but for Sky) more flexible than the OLS results. This implies that the consequences of measurement error induced by the time lag between when decisions are made in the UK advertising market and when the data underlying this study were realized tends to bias upwards (i.e., smaller in absolute value) estimated inverse demand flexibilities. There are substantial differences in the cross-flexibilities, which are mostly estimated to be zero in the OLS results but positive in the IV results. These cross-flexibilities provide an 'amplification mechanism' by which increases in impacts for one channel, while lowering its price, increases prices for other channels, influence their revenues. We show in the next section that the net effects of these biases is for the OLS estimates to generally understate the revenue response to increases in advertising minute regulations.

6.   Counterfactual Analysis of Changes in Limits on Advertising Minutes

6.1   Preliminaries

Media regulators across Europe have recently been evaluating existing limits on the amount of television advertising their PSBs are permitted to show. [46] In the UK, PSBs can provide a daily average of 7 minutes per hour of advertising,

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[45]While some channel pairs have point-estimates that suggest they are complements, Table 3 shows that none of these are statistically significant using our preferred IV estimates.

[46]As discussed in the Introduction, in 2016 the European Commission considered relaxing its 12 minute per hour regulation due to rising competition from Internet Video. After consulting with sector regulators in the member countries (who generally impose stricter limits than the EU directive), the Commission ultimately kept the regulation unchanged.

while non-PSBs can provide an average of 9 minutes per hour. As part of a review of the television advertising sector in 2007, the UK media regulator, Ofcom, considered whether changes in those limits may help it achieve its regulatory objectives "to further the interests of citizens and consumers ... in relation to ... [inter alia] ... the range, quality, and appeal of television services throughout the UK." ((Ofcom, 2008, p9)). In the consultation evaluating this issue, it considered three different trajectories for advertising minutes: (1) maintaining the status quo (which we will refer to as "baseline"), (2) "harmonizing up", and (3) "harmonizing down," where harmonizing up (down) would eliminate the difference in regulatory treatment between PSBs and non-PSBs by allowing PSBs to advertise up to a daily average of 9 minutes per hour (requiring non-PSBs to advertise no more than a daily average of 7 minutes an hour).[47] This review was placed on hold during the Great Recession of 2008 and 2009 and advertising minute regulations have since remained unchanged.[48]

In this section, we evaluate the consequences of each of the harmonizing up and down options based on our estimates of the inverse demand for advertising in the UK television advertising market. We base our revenue predictions on 2008 values of the explanatory variables, the last full year for which we have data. We conduct simulations for each channel using a parametric bootstrap from the distribution of regression coefficients implied by the results in Tables 1 and 2. We draw 1000 coefficient samples for each channel separately and later combine them to predict industry effects. To consider the effect of each proposed change in impacts, we set all right-hand-side variables at their year-2008 means from January 2009 onwards (except the month dummies) and predict sequences of channel revenue paths.[49] In the baseline scenario, we keep impacts at their year-2008 averages and forward-simulate log prices based on our parameter estimates for each bootstrap sample. Revenue in a given month is then calculated as the product of the exponentiated log price with the quanity of impacts. In each counterfactual scenario, we set impacts at their new (unchanged, increased, or decreased, depending on the policy scenario) level beginning in January 2010. This changes

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[47]In the consultation, Ofcom used the terms "levelling up" and "levelling down". They also considered changing the restrictions on advertising minutes within sub-periods of the day, for example during peak periods. The nature of our data set with key variables at monthly time frequency mean we are unable to consider such changes. See (Ofcom, 2008, pp11-20) for more details.

[48]Changes in advertising minute regulations were again considered in 2010, but were delayed due to competition concerns that caused Ofcom to consider referring the industry to the UK Competition Commission (CC) for a market investigation (Ofcom (2011)). In December 2011, Ofcom decided both to refrain from referring their concerns to the CC and to leave advertising minute restrictions unchanged.

[49]One could also imagine conducting counterfactual simulations based on predicted paths of impacts after 2008 rather than fixing impacts at their 2008 levels. However, the purpose of our counterfactuals is not to predict the evolution of the industry, but to suggest the likely effects relaxing (or tightening) advertising minute limits would have on channel revenues however the industry evolves.

the log impact variables in each equation directly and changes the log SOCI for year 2011 onwards by shifting each channel's relative share of impacts. We again forward-simulate log prices based on our estimates for that bootstrap sample and predict the revenue path. We simulate revenues forward as far as needed, finding that all dynamics are resolved by the end of 2012. In our results below, we compare the average (across bootstrap samples) annual revenue for each channel in 2009 against that in 2012.[50] Annual averages are useful because they smooth out the variability in results due to across-month differences in predicted prices and revenues.

Before presenting our results, we describe how much impacts were forecast to change under each of the proposed policies considered by Ofcom. While it would seem that they would simply rise or fall by the appropriate ratio, this misses the fact that the limits are daily averages and that channels can deviate from those averages within individual clock hours. For example, all channels provide advertising far above the daily average in peak periods when viewership is highest so as to maximize the impacts they can deliver from their ad minutes. As such, allowing PSBs to provide a daily average of 9 minutes/hour instead of the current 7 will not increase impacts as much as 28.6% (=9/7) as all channels would still be restricted from providing more than 12 minutes in any clock hour. Ofcom was well aware of this restriction and therefore calculated the likely change in impacts that would result from both the harmonizing up and harmonizing down scenarios. Table 4 summarizes the changes in impacts predicted by Ofcom.

Table 4: Changes in Advertising Minutes under Harmonizing Up and Harmonizing Down

Channel	Harmonizing Up	Harmonizing Down
ITV1	8.0%	0.0%
C4	12.3%	0.0%
Five	10.0%	0.0%
Sky	0.0%	-6.9%
PSB Digitals	0.0%	-6.9%

Notes: These are the estimated changes in impacts that would arise from "Harmonizing Up" advertising minutes for PSBs from a daily average of 7 minutes per hour to the 9 minutes per hour currently allowed non-PSBs and "Harmonizing Down" advertising minutes for non-PSBs from a daily average of 9 to the 7 minutes per hour currently allowed PSBs. Source: (Ofcom, 2008, pp74,76). Results for the PSB Digitals were not provided in the Ofcom table. We have assumed that their impacts fall by an amount equal to that for non-PSBs as a whole (6.9%).

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[50]We chose to compare annual revenue in 2012 to the 2009 values so that we are comparing revenues that come directly from the prediction excercise, rather than the data in 2008 and the model in 2012. There is little qualitative difference in results if we choose to compare 2008 to 2012.

Table 5: Revenue Effects of Upward Harmonization - IV Estimates.

	Baseline (£mill.)	Harmonizing Up (£mill.)	Difference (£mill.)	Percentage Change
ITV1	1,037	1,146	109	10.56
	(35.75)	(42.99)	(30.12)	(2.94)
C4	533	580	48	9.00
	(22.32)	(26.10)	(19.18)	(3.69)
Five	207	236	29	13.83
	(7.31)	(21.51)	(17.24)	(8.01)
Sky	547	555	8	1.53
	(14.83)	(35.63)	(34.23)	(6.34)
PSB Dig.	344	328	-16	-4.77
	(19.72)	(34.37)	(19.55)	(5.91)
Total PSB	1,777	1,963	186	10.45
	(45.94)	(76.04)	(57.04)	(3.19)
Total Industry	2,668	2,846	178	6.69
	(39.12)	(74.51)	(69.94)	(2.64)

Notes: Bootstrap Standard Errors, in parentheses, are calculated as the standard deviation across the 1000 draws. This table reports counterfactual long-run channel, total PSB, and total industry revenue based on our IV inverse demand estimates for the policy of upward harmonization that allows public service broadcasters (PSBs) to air the same number of advertising minutes per hour as non-PSBs from 1 January 2010, an increase from 7 to 9 minutes/hour (168 to 216 minutes/day). Predicted revenue arises for any month by setting the explanatory variables in each equation to their average 2008 values (plus the impacts and implied SOCI from the policy change from 2010), predicting (log) prices, and multiplying them together. This is done for every month for 1000 bootstrap replications of our analysis, the baseline (2009) and long-run (2012) averages of which are reported here. Revenue is measured in million January 2002 British pounds. The corresponding values of this analysis for our OLS results are provided in Appendix Table A.

6.2 Counterfactual Results

Tables 5 and 6 demonstrate the effects of each proposed policy on each channel or channel group included in our analysis, as well as for all PSBs and the industry as a whole.[51] In a nutshell, harmonizing up is estimated to increase PSB and industry revenue whilst harmonizing down is estimated to leave both unchanged.

Consider first harmonizing advertising minutes for PSBs up to the level now enjoyed by non-PSBs. Table 5 shows that harmonizing up is estimated to increase the annual revenue for PSB channels by 10.6% for ITV1, 9.0% for C4, and 13.8%

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[51]Revenue predictions that arise from the the OLS inverse demand estimates are presented in Appendix Tables A and B. As suggested earlier, the OLS results underestimate the revenue effects when compared to the IV results presented here, although do yield tighter standard errors around their predictions. Qualitiatively the results are similar.

for Five. There are negligible estimated long-run effects for Sky or the Digital channels owned by the PSBs. The estimated effect for PSBs as a whole is an increase in revenue of an estimated 10.5% and for the industry as a whole an increase in revenue of 6.7%. Each of the effects for ITV1, C4, PSBs as a whole, and the industry as a whole are is statistically significantly different from zero at conventional significance levels.

The relatively large revenue increases for each of the three main PSB channels stem from two effects. For ITV1 and Five, which are estimated to have inflexible long-run demand, the increase in advertising minutes directly increases revenue by increasing own channel impacts. For Channel Four, whose long-run demand is estimated to be flexible, this is not the case - an increase in own impacts stemming from more advertising minutes is predicted to decrease long-run revenue. However, these own-flexibilities are not the entire story - estimated cross-flexibilites play a role in determining revenue. The long-run cross-flexibilities reported in Table 3 suggest that increases in impacts from other PSBs influence channel revenues. Since these cross-flexibilities are positive and indicate complementarity between PSB channels, increases in impacts from other PSBs lead to increases in revenues. For ITV1 and Five, these cross-flexibilities augment the revenue increases from the inflexible demand. Whilst for Five, the positive revenue effects from the cross-flexibilities overcome the revenue decrease from having flexible own long-run demand.

Table 6 demonstrates our predicted revenue effects when a policy of downward harmonization is implemented. Sky and the PSB digitals are estimated to experience revenue losses (although only for the PSB Digitals is the effect statistically significant). Revenue for ITV1 is estimated to rise by 4.2% whilst other PSB channels are estimated to have no change in revenue. PSB and Industry revenue are expected to be unchanged as a result of the decrease in ad minutes on Sky and the Digital PSBs.

The economic mechanisms at play in the downward harmonization scenario are slightly different to those discussed in the upward harmonization case. Channel Four and Five are unaffected because prices for these channels advertising are estimated to not be responsive to changes in the impacts of Sky and the PSB Digitals. The estimated long-run flexibility for ITV in response to Sky Impacts is -0.49 which suggests that prices for ITV impacts rise when impacts on Sky fall under the change in regulation. This is because advertisers will want to substitute away from Sky across to ITV1, it's largest competitor, because it now has relatively more impacts which, in turn, drives up ITV prices. PSB Digitals experience the biggest loss because the estimated positive cross-flexibility between them and Sky delivers an additional revenue decrease on top of the own-flexbility effects. The increase in ITV revenue counterbalances the large fall in revenues incurred by the PSB digitals, leaving industry revenue unchanged although there is a predicted reallocation of revenues across channels towards ITV1.

Table 6: Revenue Effects of Downward Harmonization - IV Estimates.

	Baseline (£mill.)	Harmonizing Up (£mill.)	Difference (£mill.)	Percentage Change
ITV1	1,037	1,081	44	4.20
	(35.75)	(49.44)	(23.65)	(2.22)
C4	533	535	2	0.45
	(22.32)	(24.95)	(12.74)	(2.38)
Five	207	208	1	0.43
	(7.31)	(12.07)	(7.15)	(3.43)
Sky	547	543	-3	-0.56
	(14.83)	(22.85)	(21.20)	(3.93)
PSB Dig.	344	295	-48	-14.20
	(19.72)	(27.10)	(11.09)	(3.75)
Total PSB	1,777	1825	47	2.64
	(45.94)	(67.44)	(38.15)	(2.12)
Total Industry	2,668	2,663	-4	-0.16
	(39.12)	(53.74)	(38.03)	(1.42)

Notes: Bootstrap Standard Errors, in parentheses, are calculated as the standard deviation across the 1000 draws. This table reports counterfactual long-run channel, total PSB, and total industry revenue based on our IV inverse demand estimates for the policy of downward harmonization that restricts non-PSBs to air the same number of advertising minutes per hour as PSBs, a decrease from 9 to 7 minutes/hour. Predicted revenue arises for any month by setting the explanatory variables in each equation to their average 2008 values (plus the impacts and implied SOCI from the policy change from 2010), predicting (log) prices, and multiplying them together. This is done for every month for 1000 bootstrap replications of our analysis, the baseline (2009) and long-run (2012) averages of which are reported here. Revenue is measured in million January 2002 British pounds. The corresponding values of this analysis for our OLS results are provided in Appendix Table B.

Discussion.   Two brief comments are in order about the identification of these counterfactual policy effects. First, is it reasonable to predict counterfactual revenue effects for levels of advertising minutes not previously seen in the data? Our answer is yes. The key consequence of changes in advertising minutes is that they allow broadcasters to sell more or fewer *impacts*. While the number of advertising minutes may never have reached a daily average of 9 minutes per hour for PSBs, the associated impacts that would arise under such a policy has arisen before: the advertising impacts implied by both the harmonizing up and harmonizing down policies are impacts that have previously arisen in the market.

Second, it is worth noting the difference in results that arises when one uses an IV approach compared to simple OLS. Tables A and B in the Appendix report the estimated effects of the policies of upward- and downward harmonization using our OLS results. The difference is noticeable. Looking across the upward harmonization results in Table A we see revenue increases about half the size for the PSBs. At the Industry level we predict revenue increase of 2.83% (compared to 6.6% above), but we cannot reject that there would be no effect at all. This reinforces the importance of using IV in the presence of the types of measurement error likely to arise in the UK advertising market.

7.   Conclusion

In this paper, we use a unique, proprietary dataset to estimate the inverse demand for advertising across five channels or channel groups in the UK television market. We find that long-run inverse demand is largely *inflexible* (akin to finding that long-run demand is elastic), although the effects differ significantly across channel groups. We use the results of our analysis to evaluate the impact of several proposed changes to television advertising limits in the UK market. We find that a policy of upward harmonization of advertising minute limits for public-service broadcasters (PSBs) to the level currently in place for non-PSBs would increase advertising revenues for each of the main UK PSBs (ITV1, C4, and Five) and also increase total industry revenue. While we do not measure the consequences of increased advertising minutes on the television viewer experience or the effectiveness of advertising, we nonetheless conclude that permitting more PSB advertising minutes should be considered to help support PSBs in the face of increased competition from both multi-channel television providers and the Internet.

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A. Counterfactual Revenue Predictions for Upward Harmonization - OLS Results

Table A: Revenue Effects of Upward Harmonization - OLS Estimates.

	Baseline (£mill.)	Harmonizing Up (£mill.)	Difference (£mill.)	Percentage Change
ITV1	980	1,048	68	6.97
	(38.25)	(52.91)	(36.11)	(3.69)
C4	497	519	22	4.45
	(17.31)	(20.05)	(21.56)	(4.40)
Five	210	221	11	5.30
	(8.44)	(11.32)	(6.23)	(2.95)
Sky	542	531	-10	-1.87
	(21.38)	(35.36)	(34.88)	(6.68)
PSB Dig.	362	344	-17	-4.94
	(18.19)	(32.98)	(19.85)	(5.71)
Total PSB	1,686	1,787	101	6.01
	(55.89)	(68.54)	(44.54)	(2.66)
Total Industry	2,590	2,663	73	2.83
	(53.59)	(100.89)	(79.19)	(3.06)

Notes: Bootstrap Standard Errors, in parentheses, are calculated as the standard deviation across the 1000 draws. This table reports counterfactual long-run channel, total PSB, and total industry revenue based on our OLS inverse demand estimates for the policy of upward harmonization that allows public service broadcasters (PSBs) to air the same number of advertising minutes per hour as non-PSBs from 1 January 2010, an increase from 7 to 9 minutes/hour (168 to 216 minutes/day). Predicted revenue arises for any month by setting the explanatory variables in each equation to their average 2008 values (plus the impacts and implied SOCI from the policy change from 2010), predicting (log) prices, and multiplying them together. This is done for every month for 1000 bootstrap replications of our analysis, the baseline (2009) and long-run (2012) averages of which are reported here. Revenue is measured in million January 2002 British pounds. The corresponding values of this analysis for our IV results are provided in Table 5.

B. Counterfactual Revenue Predictions for Downward Harmonization - OLS Results

Table B: Revenue Effects of Downward Harmonization - OLS Estimates.

	Baseline (£mill.)	Harmonizing Up (£mill.)	Difference (£mill.)	Percentage Change
ITV1	980	1,011	31	3.21
	(38.25)	(35.47)	(16.93)	(1.78)
C4	497	493	-4	-0.88
	(17.31)	(18.68)	(9.16)	(1.84)
Five	210	209	-1	-0.26
	(8.44)	(9.16)	(5.00)	(2.38)
Sky	542	556	14	2.82
	(21.38)	(20.80)	(34.02)	(8.67)
PSB Dig.	362	327	-35	-9.78
	(18.19)	(34.51)	(11.92)	(3.52)
Total PSB	1,686	1,712	26	1.56
	(55.89)	(58.20)	(25.94)	(1.55)
Total Industry	2,590	2,595	5	0.19
	(53.59)	(58.69)	(27.54)	(1.10)

Notes: Bootstrap Standard Errors, in parentheses, are calculated as the standard deviation across the 1000 draws. This table reports counterfactual long-run channel, total PSB, and total industry revenue based on our OLS inverse demand estimates for the policy of downward harmonization that restricts non-PSBs to air the same number of advertising minutes per hour as PSBs, a decrease from 9 to 7 minutes/hour. Predicted revenue arises for any month by setting the explanatory variables in each equation to their average 2008 values (plus the impacts and implied SOCI from the policy change from 2010), predicting (log) prices, and multiplying them together. This is done for every month for 1000 bootstrap replications of our analysis, the baseline (2009) and long-run (2012) averages of which are reported here. Revenue is measured in million January 2002 British pounds. The corresponding values of this analysis for our IV results are provided in Table 6.

C. Final Instruments for IV Regressions

Table C: Instruments used IV Estimation of Inverse Demand Curves.

	Log CPT ITV1	Log CPT C4	Log CPT Five	Log CPT Sky	Log CPT PSB Dig
Lag 1 Impacts					
ITV1	X				X
C4		X	X	X	
Five	X	X	X	X	X
Sky	X	X	X	X	X
PSB Dig.	X	X	X	X	X
Lag 2 Impacts					
ITV1	X	X			X
C4					X
Five				X	
Sky	X	X	X		X
PSB Dig.		X		X	X
Lag 3 Impacts					
ITV1	X	X	X		X
C4					X
Five		X	X	X	X
Sky	X	X	X	X	X
PSB Dig.	X	X		X	X
Lag 12 Impacts					
ITV1	X		X	X	X
C4	X		X	X	X
Five	X	X	X	X	X
Sky		X	X	X	X
PSB Dig.	X	X	X	X	X

Notes: This table reports the final set of instruments used in the estimation of each inverse demand curve. 'X' denotes inclusion as an instrument for the inverse demand curve in each column. Instrument selection took place as follows: We started with the set of 20 possible instruments for each equation and then removed potential instruments one-by-one, as long as the F-Statistics of the First-Stage regressions were not adversely impacted. The corresponding regression results are provided in Table 5.

D. The Calculation of Long-run Flexibilities

In this subsection, we describe how we calculated the long-run flexibilities reported in Table 3.

From Equation (5) in the main text, the long-run effect of a change in $\log q_{kt}$ on $\log p_{1t}$ is given by

$$\frac{\partial \log p_{jt}^{LR}}{\partial \log q_{kt}} = \frac{\beta_{jk} + \beta_{6j}(\partial \log SOCI_{jt}/\partial \log q_{kt})}{1 - \kappa_j^1}$$

There are two long-run effects of a permanent change in log impacts of channel k, $\log q_{kt}$: a direct effect, captured by β_{jk}, and an indirect effect through the Share of (industry) Commercial Impacts offered by that channel, captured by $\beta_{6j}(\partial \log SOCI_{jt}/\partial \log q_{kt})$. This indirect effect follows naturally from the definition of SOCI:

$$SOCI_{jt} = \frac{q_{jt}}{\sum_{k=j}^{5} q_{kt}}$$

$$\log SOCI_{jt} = \log q_{jt} - \log\left(\sum_{k=j}^{5} q_{kt}\right)$$

$$\Rightarrow \frac{\partial \log SOCI_{jt}}{\partial \log q_{kt}} = \begin{cases} 1 - SOCI_{kt} & \text{if } j = k \\ -SOCI_{kt} & \text{if } j \neq k \end{cases}$$

E. Comparison of Results with Ofcom-Sponsored Studies

Portions of the analysis presented here are based on the UK Office of Communications (Ofcom) reports from May 2010 (Analysys Mason and BrandScience (2010)) and September 2011 ((Analysys Mason (2011))) described in footnote 9 of the main text. This subsection explains the differences between those reports and this paper.

In contrast to the results in this paper, both reports found that estimated own-impact flexibilities (called "inverse elasticities" in the reports) were broadly flexible, and the first report found that a policy of harmonizing down would generally increase channel revenue, while a policy of harmonizing up would generally decrease them. While the data underlying those reports and this paper are identical, there are three important differences in the econometric models implemented here that drive the differences in the estimated flexibilities and thus the predicted impact of counterfactual changes in advertising minute limits. The

first difference centres on the treatment of seasonality: the models in the Ofcom report used a subset of monthly dummies in each channel equation as opposed to the full set of dummies used in the analysis in this paper. The second difference centres on the final functional form of the econometric model: in the Ofcom reports, linear and log models were tested and a linear model was selected; in this paper, we tested linear, log-log, and Box-Cox models before selecting the log model. The third difference is that in this paper we split out non-PSB impacts into two groups: Sky impacts and PSB Digital channel impacts. Informal tests suggest it is the first of these modeling differences most responsible for the differences in predicted revenue effects.[52]

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[52]We were able to estimate flexibilities in linear and Box-Cox models and found them all to be qualitatively similar to those presented in our final results in Table 1, suggesting our functional form decisions aren't driving the differences. Furthermore, we included all the month dummies in a sample of the regressions underlying the reports and found them to indeed significantly reduce in absolute value the estimated own-channel flexibilities.