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Abstract

"Free" consumer entertainment and information from the Internet, largely supported by advertising revenues, has had a major impact on consumer behavior. Some economists believe that measured gross domestic product (GDP) growth is badly underestimated because GDP excludes online entertainment (Brynjolfsson and Oh 2012; Ito 2013; Aeppel 2015). This paper introduces an experimental GDP methodology that includes advertising-supported media in both final output and business inputs. For example, Google Maps would be counted as final output when it is used by a consumer to plan vacation driving routes. On the other hand, the same website would be counted as a business input when it is used by a pizza restaurant to plan delivery routes.

Contrary to critics of the U.S. Bureau of Economic Analysis (BEA), the process of including "free" media in the input-output accounts has little impact on either GDP or total factor productivity (TFP). Between 1998 and 2012, measured nominal GDP growth falls 0.005% per year, real GDP growth rises 0.009% per year and TFP growth rises 0.016% per year. Between 1929 and 1998, measured nominal GDP growth rises 0.002% per year, real GDP growth falls 0.002% per year, and TFP growth rises 0.004% per year. These changes are not nearly enough to reverse the recent slowdown in growth.

Our method for accounting for free media is production oriented in the sense that it is a measure of the resource input into the entertainment (or other content) of the medium rather than a measure of the consumer surplus arising from the content. The BEA uses a similar production-oriented approach when measuring GDP. In contrast, other researchers use broader approaches to measure value. Brynjolfsson and Oh (2012) attempt to capture some consumer surplus by measuring the time expended on the Internet. Varian (2009) argues that much of the value of the Internet is in time saving, an additional metric for capturing consumer surplus. The McKinsey Institute (Bughin et al. 2011) attempts to measure the productivity gain from search directly.

In particular, this production-oriented accounting has no method to account for instances in which the good or service precedes the revenue that it eventually generates. Over the past two decades, many Silicon Valley firms have followed the disruptive business model described as URL: ubiquity now, revenue later. Some firms have been creating proprietary software or research, which is already captured in the national accounts as investment. Other firms have been creating intangible investments in open source software, customer networks and other organizational capital. Despite their long-run value, none of these intangible assets are currently captured in the national accounts as investment. If we treat these asset categories as capital, then the productivity boom from 1995 to 2000 becomes even stronger and the weak productivity growth of the past decade may be ameliorated somewhat.

Keywords: Internet, productivity, advertising, measurement, GDP

JEL Classifications: C82, L81, M37, and O3

Introduction

Stiglitz, Sen, and Fitoussi (2009) argued that measured gross domestic product (GDP) is not a perfect proxy for welfare. One frequently discussed discrepancy between welfare and GDP is "free media." Facebook contributes directly to consumer welfare, but that contribution is not currently captured in the final expenditure part of GDP. We outline an experimental methodology to capture Facebook or Google's contribution to consumer welfare while staying within the framework established by the official guideline for national accounting, the System of National Accounts (SNA) 2008 (United Nations Statistics Division, 2008). As with owner-occupied housing, we impute production and consumption even though no money changes hands.

We impute a barter transaction between media users and media companies: Media users watch ads in return for free content. Our experimental methodology has two balancing components at its heart. On the expenditure side, we impute media purchases equal to the cost of providing media services. These costs are paid by advertisers, so free apps are actually advertising-supported entertainment. Media could have been supplied through non-advertising-supported media, and, indeed, they can be considered as having been bid away from alternatives. For example, driving directions can be downloaded from an advertising-supported website such as Google or subscriber-supported websites such as PC*MILER.

The identity of the user determines both the terminology used and the impact on measured GDP. When consumers use free media, we call the media "consumer entertainment" and add the value of that entertainment to personal consumption expenditures (PCEs) and GDP. Balancing that additional PCE, we impute income to viewers who are, in effect, paid to view advertising, with those payments being equal to the cost of providing entertainment programs. This additional income precisely equals the additional PCE, so there is no change in household savings. When businesses use free media, we call the media "business information" and add the value of that information to intermediate inputs. Balancing the additional intermediate input, we impute business output for ad viewership. This additional business output precisely cancels out the additional expenditures on intermediate inputs, so measured value added and GDP do not change. However, measured productivity may change because outputs and inputs have different prices.

This paper recalculates productivity growth when free media are included as both final output and business inputs. We estimate the contribution of free media from the supply side by measuring the advertising expenditures that support them. That is, we do not directly capture the value of Google Maps but only measure the cost of providing it. This can be interpreted as a lower bound on the contribution of these free media to output and productivity, but it is consistent with the standard methodologies for estimating an industry's contribution to output and productivity. Therefore, our supply side numbers will be comparable with other productivity research.

This paper studies four separate categories of advertising-supported media: (1) print newspapers and magazines, (2) broadcast television and radio, (3) cable and other nonbroadcast television and radio, and (4) online media. Within each category, some media products receive all of their revenue from advertisers, and others receive a portion from advertisers and a portion from subscribers. Our experimental methodology considers all advertising revenue to be the same, whether or not it is supplemented by subscription fees. Unwanted media such as telemarketing, junk mail, and spam e-mails are excluded from our research. We also exclude free media such as PBS that are supported by governments and nonprofits because these media outlets are already counted in GDP as part of government or nonprofit output. Later in the paper, we will show that each media category displays very different growth rates over time, so researchers who focus on online media may overestimate the overall impact of as-supported media. This paper focuses on measuring GDP in the United States from 1929 to 2013. In an earlier paper, we studied the impact of free media on cross-country GDP (Nakamura and Soloveichik 2015).

Our paper is divided into five parts. Section 1 provides background information on the current methodology for handling advertising-supported media in GDP. We then describe our experimental methodology in more detail and review the previous literature on advertising-supported media and entertainment. Section 2 collects data on advertising-supported media revenue and advertising-supported media use in the United States. We then use that data to recalculate nominal output and nominal GDP from 1929 to 2013. Section 3 introduces our price indexes for free media and advertising viewership from 1929 to 2013. Section 4 calculates real output, real inputs, and productivity by industry using the earlier data on nominal output and prices. In this section, our productivity numbers are calculated using the standard formulas, so

they may not reflect special features of the online media industry. Section 5 discusses how network effects impact the online media industry. We then calculate how measured total factor productivity (TFP) might change when network effects are included. This section is speculative. Finally, we include two appendixes with more detailed information for interested readers. Appendix A shows how our methodology changes the input-output accounts and other industry statistics. Appendix B describes the data used.

Section 1. Conceptual Discussion of Advertising-Supported Media

Measuring Gross Domestic Product and Consumer Surplus

We start with a general discussion of how the U.S. Bureau of Economic Analysis (BEA) measures the economy. Below is a simple supply-and-demand graph from Economics 101:

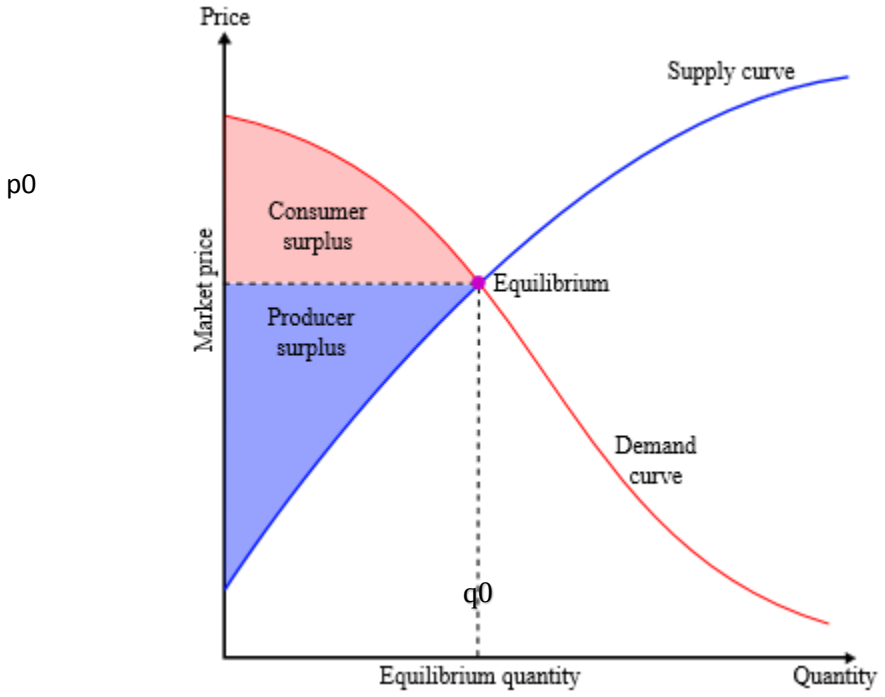

Figure 1

Figure 1 has three areas that are potentially interesting to economists. The rectangle with dotted lines shows spending: How much are consumers *actually* spending on the good studied? The red triangle shows consumer surplus. In other words, how much would consumers be *willing* to spend on the good over and above the market price? Finally, the blue triangle shows producer

surplus: How much profit do producers make from the good in question? In this figure, total output is p0q0, the area of the rectangle shown with the dashed lines.

When productivity increases and the supply curve shifts down and to the right, price falls from p0 to p1, quantity increases from q0 to q1, the red triangle expands, and the blue triangle shifts downward and to the right. The consumer now pays p1q1, and consumer surplus is now much larger. An upper bound to the increase in consumer surplus is captured in a quantity index that values the added production (q1–q0) at the old, higher price p0 so that the real output increases to the rectangle bounded by the dashed horizontal line and the solid vertical line. Thus, the real increase in output, measured at prices in the base year (p0), captures the increase in consumer surplus.

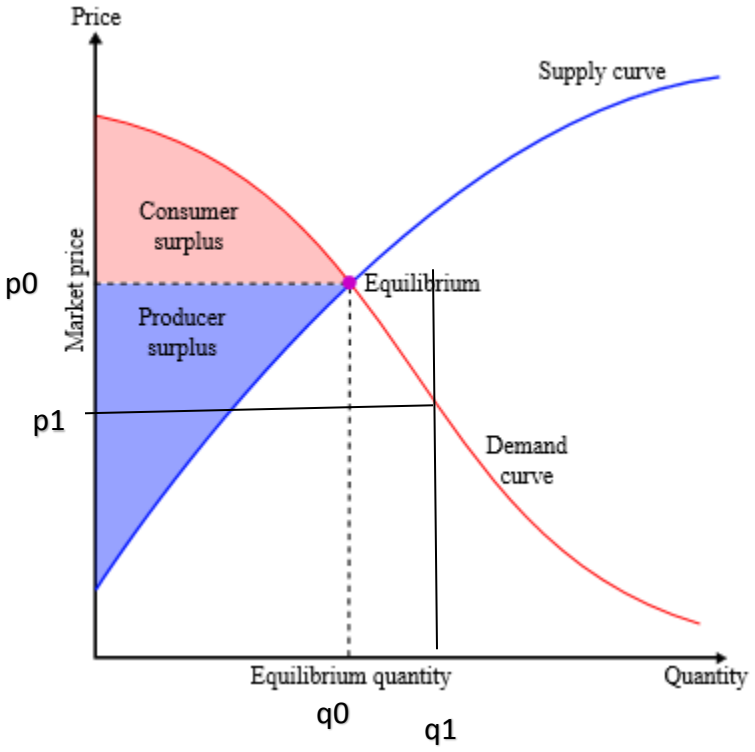

Figure 2

Advertising-supported media have zero out-of-pocket costs for consumers. Therefore, the dotted rectangle has no volume, and BEA's current methodology assigns no value it. Advertising-supported media's impact on the consumer is thus inherently difficult to capture in measures of economic output. Brynjolfsson and Oh (2013) attempt to capture some consumer

surplus by measuring the time expended on the Internet. Varian (2009) argues that much of the value of the Internet is in time saving, an additional metric for capturing consumer surplus. He performs a back-of-the-envelope calculation of the savings of time from search based on the search time savings estimate in Chen et al. (2013), which is 15 minutes per search. Noting that, on average, Americans search once a day, then calculating the average value of time as $22 for employed workers, and multiplying by the number of employed workers, Varian concludes that Google saves Americans $65 billion a year.

However, these measures of consumer surplus are based on an implied opportunity cost of leisure time, with leisure time being based on surveys. This implied value of leisure time is estimated based on regression analysis and has not been used in other contexts within GDP measures. In particular, we do not have a clear idea of how closely tied this measure of consumer surplus might be to economic activity. To make the argument differently, the weather may have a large impact on how much consumers enjoy certain recreational activities, but because this weather impact is not closely tied to economic activities, we do not include it in GDP; by comparison, the improvement in consumer surplus captured in the demand-supply diagram is very closely tied to economic activity and direct economic measures.

This paper uses an experimental methodology to value advertising-supported media. Our estimated value is based on the *actual* costs of producing free media. By design, our estimated value is calculated using very similar methodology to the BEA's published GDP statistics. Accordingly, we can compare our estimated value for free media with overall GDP without conceptual problems. Furthermore, we can also use standard productivity formulas to calculate the productivity impact of free media by industry. It should be noted that when we measure value from the cost side, we may not track consumer surplus or consumer welfare as closely as we would in the presence of prices. A similar problem arises in the measure of the real output of government services such as public education or national defense. Nevertheless, our production-oriented accounting is much less dependent on modeling assumptions than competing estimation techniques.

Measuring Total Factor Productivity and Total Factor Productivity Growth

Productivity researchers generally work with a stylized model of the firm, which uses inputs and produces output for sale in the market. The basic problem for TFP measurement is shown in Figure 3 below.

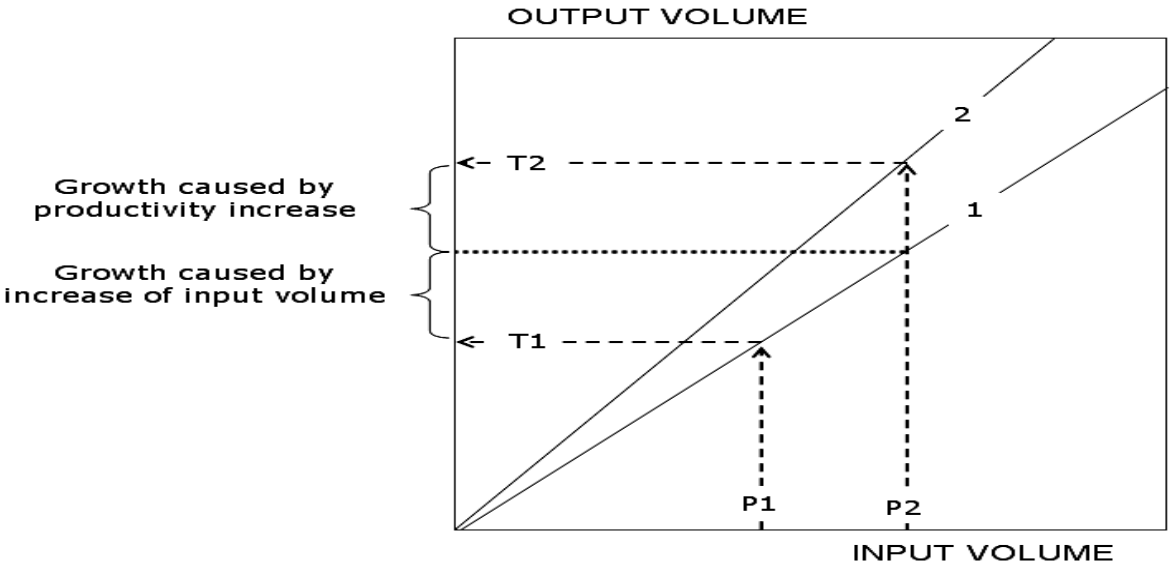

Figure 3

If all inputs were held completely fixed, TFP growth would be easy to measure. The formula to calculate TFP growth would simply be:

$$\text{TFP growth from years 0 to t} = (\text{Output}_t)/(\text{Output}_0)$$

However, the situation is much more complicated when inputs change over time. In that case, researchers need to break down the problem into two stages. First, they estimate the output that would be produced in year t *if* technology and other outside factors were held fixed from year 0 to t. After they've made this estimate, they calculate:

$$\text{TFP growth from years 0 to t} = (\text{Output}_t)/(\text{Predicted Output}_t)$$

Unfortunately, predicting output is a hard problem. Most researchers studying TFP use a productivity formula that implicitly predicts output from input changes. That standard productivity formula is based on a simplified model that assumes constant returns to scale, smooth production functions, and competitive industries with profit-maximizing firms. In addition, current output and prices are assumed to be unrelated with past output or prices.

Obviously, this simplified model is not a perfect match for Silicon Valley firms. For example, the URL (ubiquity now, revenue later) business model assumes that lower prices now help companies become more efficient and eventually profitable. This completely contradicts the assumption that current output is unrelated with past prices. However, many other industries also violate some of the assumptions listed earlier. A researcher who tried to account for all the complexities of each industry would quickly find the calculations impossible. Most researchers use the standard productivity formula as a starting point when comparing TFP across industries, over time, or across countries. We will follow the literature and use the standard TFP formula to estimate the impact of free apps on aggregate productivity. For more discussion on TFP measurement, see Jorgenson et al. (2015).

Current Treatment of Advertising-Supported Media[1] in System of National Accounts 2008 and the U.S. National Income Accounts

In the SNA 2008 and the U.S. BEA national income and product accounts, advertising-supported media are treated simply as intermediate input to the production of advertising slots. If we think of soap as being the advertised good, then a YouTube video produced to entertain households is an expense of the media company, which then sells the advertising slot to the soap manufacturer. In turn, the cost of the advertising slot is an expense of the soap manufacturer, just like physical inputs such as lye or fat. In this treatment, there is no directly measured consumption benefit to the consumer of the entertainment provided except to the extent that the consumer pays for the

[1] Our discussion assumes that media companies earn money by selling advertising services to outside companies, but the economics are the same if media companies collect and sell private information for nonadvertising purposes such as product design. We just use the word *advertising* because it would be too cumbersome to say *advertising or information collection*.

hardware and services associated with receiving the entertainment, such as the computer or Internet service.

The difficulty with that treatment is advertising-supported media provide a much greater value to consumers than the cost of a television set. Because advertising-supported media provide so much value to consumers, it seems wrong not to count these media in the final output. This difficulty is highlighted when television or the Internet bids entertainment or content providers, such as NFL teams, away from the paid entertainment sector into advertising-supported media. Under the current treatment, these sports teams cease to provide consumer recreation services and become advertising instead. A consequence is that, in the 1950s, for example, real consumer recreation services declined in a period when real personal consumption per capita rose substantially because households switched from movies to television as their prime source of entertainment. Another way to think about this is to consider how the value of a television set to the consumer is affected by an increase in the number of ad-supported channels being broadcast. The increased variety increases consumer choice and, therefore, welfare. Should this improvement in welfare be reflected in the quality-adjusted price for television sets? Holding nominal output fixed, this decline in quality-adjusted prices for television sets would result in a real output increase for the television equipment–producing industry. In turn, this real output increase would result in an increase in measured TFP even if there is no change in the direct product or process of the television equipment–producing industry.

It is useful to clarify the conundrum with the following highly stylized model. We consider a soap manufacturer, an entertainer, and households.[2] The soap manufacturer must advertise to sell the soap. Initially, the soap manufacturer spends $550 to make the soap, spends $250 on advertising with no entertainment value, and sells 800 bars of soap for $1 each. The entertainer sells 100 tickets to her act for $2 each. One hundred households each spend $8 for soap and $2 for entertainment. Now, suppose the soap manufacturer pays the entertainer $200 to include an advertisement for soap in her program and cuts other costs by $200. The entertainer now allows the same 100 households to attend her act without charging for tickets. The 100

[2] For simplicity, we assume that the entertainer produces and broadcasts the content by herself. In a more realistic model, the soap company might purchase advertising slots from a broadcasting company. In turn, that broadcasting company might purchase content from a production studio. The imputed barter transaction of advertising viewership in return for content is the same and measured GDP is the same.

households receive the soap and the entertainment but pay only the $8 per household for soap (and listen to a soap announcement). For simplicity, we assume that the demand for entertainment is unaffected by this switch. In other words, households act as if they were paying $2 for the entertainment, but instead, they are viewing the advertising and they appear to perceive that viewing the advertising costs them $2 each. Roughly speaking, the households consume the same amount but pay less out of pocket.

In the current national income accounts treatment, output drops. The entertainment is no longer measured as part of personal consumption, only the soap is. In the initial case, $1,000 in economic resources was used to produce $1,000 in consumption output. With advertising-supported entertainment, $800 is used to produce $800 in consumption output. Effectively, $200 has disappeared from real output. However, this appears to be a misrepresentation in that the households are still consuming the same real amount of entertainment, but it has disappeared from measured output.

One possible treatment would be to view the entertainment with advertising as having the same real value but falling in price to zero. That is, nominal output is $800, but real output is $1,000. While we do not actually observe the market value to the consumer of the entertainment in most cases, we can impute the market value from the payment to the entertainer. But the some economic formulas do not work well when analyzing goods and services with zero prices. For example, it is difficult to explain why consumers sometimes pay to avoid advertising if the price for advertising-supported media is zero. Furthermore, if the situation should reverse and a price be paid, the rate of inflation for that item cannot be calculated.

A more satisfactory treatment, proposed by Cremeans (1980), and pursued in this paper, would be to consider the transaction as a barter trade of entertainment received by the consumer in exchange for which the consumer agrees to view the advertisement. We would record a dollar as paid by the consumer to the soap manufacturer for the entertainment, and the soap manufacturer would pay the dollar back to the consumer for viewing the advertisement. In this treatment, advertising-supported media are reflected in the real income and consumption of the consumer. The amount mirrors the true value of entertainment to modern society and in a way that finds parallels with the treatment of similar products with no out-of-pocket price, such as residential services of owner-occupied dwellings and financial services of checking accounts.

An alternative satisfactory treatment was recently proposed by Charles Hulten. He argued that free media can be viewed as a gift from media companies to consumers. In that case, we record the entertainment received by the consumer but do not record any service received by the media company. Conceptually, this is parallel to the treatment of nonprofit organizations serving households. This treatment has the same impact on measured GDP and gross industry output as the Cremeans (1980) treatment. But it is unclear how to attribute output gains when businesses receive inputs as gifts from other businesses. The gift raises the output of the gifting business without lowering the value added of the gifted business. This violates the balancing of gross output with inputs that underlies productivity accounts.

Previous Research on Noncash Payments in GDP

Our experimental methodology does not require any major conceptual changes to SNA 2008. In this paper, we treat advertising-supported media as payment in kind for services produced by households. SNA 2008 already counts other noncash payments as labor income (Section 7.51). SNA 2008 also imputes cash values for barter transactions (Section 3.75), owner-occupied housing (Section 6.34), and financial services indirectly measured (Section 6.163). Just as with those transactions, we impute a value for advertising-supported media based on estimated costs. However, because the household is not "employed" by the media producer, we treat the household production of the service of providing access to advertising as a form of production by an unincorporated household enterprise. To minimize the deviation from BEA's official accounts, we do not consider the production process for this advertising viewership. We intentionally avoid this because of the plethora of issues involved in measuring household production.

Our paper is not the first to discuss treating advertising-supported media as payment in kind. Imputation for advertising-supported media was first raised in the *National Income—1954 Edition* and was extensively discussed in the 1970s (Ruggles and Ruggles 1970; Jaszi 1971; Okun 1971; Juster 1973; Eisner 1978; Kendrick 1979). Cremeans (1980) estimated that

advertising-supported media were worth $28 billion in 1976.[3] Vanoli (2005) discusses this issue in *A History of National Accounting*. More recently, *Businessweek* (Ito 2013) and the *Wall Street Journal* (Aeppel 2015) published articles criticizing the BEA's GDP numbers for excluding free online media. In addition, we have previously written papers studying advertising-supported media and advocating that such media be treated as a payment in kind (Nakamura 2015; Soloveichik 2014; Nakamura and Soloveichik 2015).

This paper extends the earlier research by considering how to account for the URL model within our methodology and by developing input-output and productivity accounts for advertising-supported media. Similar to other productivity statistics, this decomposition does not directly change aggregate GDP measurements. Instead, the decomposition allows researchers and policymakers to better understand the sources of GDP growth. In particular, our productivity statistics show faster TFP growth in the online media industry and slower TFP growth elsewhere.

Effects on Measured Consumer Welfare, Productivity, and Other Summary Statistics

Our experimental methodology produces more intuitive welfare comparisons. In the United States, many sporting events are now moving from broadcast television to cable television. Since cable television networks generally show the same amount of advertising as broadcast networks, consumers are unambiguously worse off because of the switch: They are now required to pay subscription fees for content they had previously viewed for free; as a result, some refuse to pay the new fees and forego the entertainment. Yet, SNA 2008's methodology treats the new cable subscribers as a real GDP increase. Under the alternative method, real GDP falls. This drop in viewership is considered a decrease in final expenditures. Nominal GDP will likely rise with the switch from broadcast television to cable television. However, that nominal GDP growth would be more than canceled by higher prices for entertainment caused by the switch.[4]

[3] For the same year, we estimate that advertising-supported entertainment added only $8 billion to GDP. The main reason for the difference is the fact that we do not count nonmedia costs and advertising-supported business information in final output. Neither our research nor the literature cited in this paragraph includes the value of amateur media production such as personal blogs in GDP.

[4] This discussion focuses on the short-term effects of a switch. In the long term, the higher earnings caused by the switch of sporting events from broadcast television to cable television may well result in more sporting events becoming available in more markets as well as in higher salaries to players, inducing higher value workers to enter

Similarly, our experimental methodology produces more intuitive productivity comparisons. In the early 2000s, many drivers purchased GPS software such as Garmin or TomTom that provided driving directions. In recent years, advertising-supported services such as Waze and Google Maps have taken over the industry. Even counting the implicit cost of viewing ads, the new advertising-supported services are cheaper to use. Accordingly, restaurants that require driving directions are unambiguously better off because the total cost of their meals has fallen, and more customers go to them. SNA 2008's methodology treats these lower costs as a TFP increase in the restaurant industry. Under the experimental method, TFP in the restaurant industry is unchanged. Instead, the TFP growth is allocated to the Silicon Valley firms offering high-quality driving directions cheaper.

By construction, the nominal income "earned" by consumers watching advertising is equal to the nominal value of entertainment "purchased." As a result, our experimental methodology has no effect on consumer savings. Similarly, the nominal income "earned" by business users watching advertising is equal to the nominal value of information "purchased," and our experimental methodology has no effect on corporate profits. If the media provider is located in the same country as the viewer, imports and exports will be unaffected. If the media company is located in a different country, imports and exports will increase by the same amount with no effect on the net nominal balance of trade.

Consumers often need to buy expensive equipment before they can enjoy advertising-supported entertainment. SNA 2008 counts televisions, radios, smartphones, and computers as consumer durable goods. However, one could argue that these consumer durables should be reclassified as capital investment if advertising-supported media are considered in-kind payment for advertising viewership. This change would have no impact on measured GDP, but it would increase capital stock and decrease the stock of consumer durables. In that case, the value of advertising-supported media would be considered mixed income and represents compensation for both the time spent watching advertising and the capital necessary to watch advertising. If SNA 2008 chose to implement our experimental methodology, the value of advertising-

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the competition and improving the quality of entertainment. In practice, measuring cable prices is tricky, and the U.S. Bureau of Labor Statistics' existing price indexes may not adjust for quality perfectly.

supported entertainment would be added to "proprietor's income" (or "mixed income" in SNA 2008 terminology) (NIPA Table 1.10, line 13). We do not pursue this approach here.

Other Research on Advertising, Brand Equity and Entertainment Originals

Our research on advertising-supported media is distinct from the rich literature on advertising. Previous researchers have studied why advertising exists and calculated how much firms should optimally spend on advertising (Dorfman and Steiner 1954; Nerlove and Arrow 1962). Other papers have argued that advertising increases sales over the long run, and therefore, advertising should be considered an investment in brand equity (Nakamura 2015; Corrado, Hulten, and Sichel 2009). All of this research is focused on the companies that purchase advertising viewership and then use it to sell products and build brand equity.[5] In contrast, our research is focused on the online media companies that produce content, barter the content for advertising viewership, and then sell the advertising viewership to the rest of the economy. None of the results in this paper depend on how companies use their purchased viewership. The only thing that matters is that companies want advertising viewership and are willing to pay for it.

Advertising-supported media are also distinct from entertainment originals. Entertainment originals are long-lived intangible assets owned by media companies and artists. It is true that entertainment originals are sometimes used to produce advertising-supported media such as television. However, the categories are not at all identical. Advertising-supported media includes short-lived media such as newspapers, sporting events, and other entertainment that is not part of capital stock. Conversely, entertainment originals are used to produce consumer products such as DVDs and books that are sold to consumers and counted in PCE. This paper uses some of the data originally collected for a project on entertainment originals (Soloveichik 2013a, b, c, d, and e), but none of the results in this paper depend on the treatment of entertainment originals in GDP.

[5] In addition, the marketing expenditures studied in these papers include more than ads shown on free media. For example, companies can increase sales with telemarketing calls, in-person sales visits, junk mail, and other products that aren't generally bundled with entertainment or useful information.

Section 2. Nominal Media Production and Consumer Entertainment

Nominal Output of Advertising-Supported Media

When measuring advertising-supported media, we study the four separate media categories discussed earlier: (1) print newspapers and magazines, (2) broadcast television and radio, (3) cable and other nonbroadcast television and radio,[6] and (4) online media. In some cases, the line between one category and the next is speculative. In particular, many websites contain articles originally produced for print publication. Our estimates of nominal media production are not sensitive to the split between the categories. However, each category has its own price index, so real growth rates may change if the split changes. Appendix B contains detailed information on the data sets used to track nominal advertising revenue and the benchmarking procedures.

Figure 4 shows advertising revenue by media category over time. Since 1998, online media have grown from almost nothing to 0.27% of nominal GDP. Over the same time period, print advertising decreased from 0.56% to 0.13% of nominal GDP. The growth of the Internet is almost certainly responsible for most of the print decline. Classified advertising has moved from newspaper sections to websites. Printed yellow pages are also being replaced by web searches. Print media advertising has also fallen in the past because of competition from radio and television. The same dynamic has been playing out more slowly in the television industry. Between 1980 and 2013, cable television grew from 0.08% to 0.41% of nominal GDP. Over the same time period, broadcast radio and television decreased from 0.34% to 0.11% of nominal GDP. Consumers are clearly willing to substitute from one media to another.

Not all of the advertising revenue shown in Figure 4 is used to produce entertainment. Media companies need a sales staff to reach out to advertisers, plan the exact format of the ads, and bill the advertisers afterward. Reporters and editors may focus on topics more useful for advertisers rather than for readers. In addition, printed media such as newspapers spend money printing ads and then stuffing them in news sections. In earlier research, we estimated that

[6] This category includes all television viewed by households with cable even if they are watching broadcast television. We also include satellite cable, online video channels hosted on YouTube, and online radio stations such as Pandora. We assume that shows on all of these media are produced and delivered with the same technology, so they have the same price index. In contrast, transmitting content over the air requires very different technology. In our sample period, cable television accounts for the majority of this category, so we sometimes refer to the category as simply "cable television."

nonmedia costs account for 50% of newspaper advertising; 72% of magazine advertising (Nakamura 2015); and 25% of television, radio, and online advertising (Soloveichik 2013a, b, c, d, and e; Soloveichik and Wasshausen 2013; and Soloveichik 2014). When calculating nonmedia costs, we assume that these within-category ratios are fixed from 1929 until 2013.

Figure 5 shows estimated share of advertising revenue devoted to media content. From 1929 to 2013, the media content share of advertising grew from 45% to 69%. This steady increase was caused by a composition shift. Figure 4 shows that print media have been steadily declining relative to the other media categories. Relative to the other media categories, print media outlets spend a much larger share of revenue on physical production costs so they have less advertising revenue available to subsidize media services. As a result, advertising-supported media have grown faster than overall advertising.

It is important to note that Figure 5 only measures the estimated cost of providing advertising-supported media, not the value that media users derive from the media. Just as with much consumer surplus, this value is not counted in either GDP or TFP.[7] Furthermore, the estimated cost is an imperfect proxy for the market price that might have been charged. This problem has been studied previously for government output, nonprofit output, and other items in which GDP methodology uses costs as a proxy for value. Finally, a fixed ratio for nonmedia costs misses variation that may occur over time. As a robustness check, we collected IRS data tracking (total expenditures) relative to total revenue by industry and year. We found that adjusting for this variation increases the value of online media during the dot.com bubble and reduces volatility over the business cycle slightly, but it has little impact on long-term results.

Media Usage by Consumers versus Businesses

Our primary data on advertising revenue is taken from the 2007 Economic Census. The Economic Census splits advertising by format and product category, but it has no data on whether consumers or businesses are viewing the ads. In a few cases, the products advertised

[7] A particular problem with media valuation is that media production costs are a lower bound on the market price that would be charged if advertising support did not exist. Media companies selling to individual users typically spend significant resources billing customers and dealing with payment issues. These costs are especially important for broadcasters and Internet publishers, which do not currently require out-of-pocket payments at all.

provide some clue about the likely industry of the user. For example, hospitals are the main purchasers of MRI machines, so magazines with ads boasting low prices for MRI machines are probably targeting hospital executives. But most websites target a general audience and have advertising unrelated to the precise media services provided.[8] According to Hal Varian, chief economist at Google, Google does not have much information on whether consumers or businesses are viewing their ads. To the best of our knowledge, no company or researcher has published any estimates of the consumer share for "free" websites, advertising-supported newspapers, and other sources.

This paper uses a variety of data sources to split media usage between consumers and businesses. For online media, we use survey data from Forrester Research. Since 2007, Forrester Research has asked survey respondents to report both "work Internet" time and "personal Internet" time. We use these data to estimate the consumer entertainment share of online media. For print media, we use genre data reported in the Economic Census and other sources to split consumers and businesses. For example, we assume that scientific journals are used for work rather than leisure. We were not able to find any data on the consumer share for radio or television. For now, we use our best judgment to pick a reasonable split. More information on the procedures used is given in Appendix B.

Figure 6 shows the estimated GDP share of advertising-supported media devoted to consumer entertainment. From 1929 to 2013, the entertainment share has hovered around 80%. Radio and television programs consistently have a higher entertainment share than average, and the Internet has a lower entertainment share. However, neither the introduction of television in the 1950s nor the introduction of Internet in the 1990s significantly changes the overall consumer entertainment share. This suggests that the overall demand for entertainment relative to business information is fixed and does not depend on the precise delivery technology.

Figure 7 shows the increase in nominal GDP from including advertising-supported entertainment. Consistent with Brynjolfsson and Oh's (2012) research, online consumer entertainment has grown enormously in the past decade and now accounts for 0.11% of nominal GDP. However, this growth is more than canceled out by a decrease in print advertising-

[8] Even when a business is using a website for work, the advertisements may still push consumer products. Conversely, consumer entertainment products might push business inputs. In both cases, the advertisers are hoping that the website users carry the message between work and home.

supported entertainment. Total advertising-supported entertainment shrunk from 0.54% of GDP in 1998 to 0.50% of GDP in 2013. As a result, nominal GDP growth decreases slightly when free media are included in final output. Between 1929 and 2013, advertising-supported entertainment has hovered around 0.5% of nominal GDP. Therefore, long-term GDP growth is almost unchanged by our experimental methodology.

Figure 8 shows the value of advertising-supported business information relative to nominal GDP. The most striking difference between Figures 7 and 8 is that advertising-supported business information is much less prevalent than advertising-supported consumer entertainment.[9] Despite the size differences, recent patterns are very similar. Just as with consumer entertainment, we find that online business information has grown dramatically, and print business information has shrunk. It is important to note that the advertising-supported business information shown in Figure 8 has no direct effect on measured GDP or aggregate value added.[10] Like all intermediate inputs, their cost is already captured in the purchase of the final output and the value added of the industries that produced the intermediate inputs. Nevertheless, these numbers are potentially useful for researchers studying gross output, productivity by industry, and other related parts of the national income and product accounts.

Comparing Our Results with the Industry Literature

In 2013, we estimate that online entertainment added $19 billion to the U.S. GDP. This is not a trivial amount, but it is far lower than alternative estimates. For 2011, Brynjolfsson and Oh (2012) estimated a value of $376 billion based on time use data.[11] The Boston Consulting Group (Dean et al. 2012) estimated a value of $500 billion in 2011, based on consumer surveys and an economic model. The much higher numbers are a consequence of different methodologies. Both

[9] Using advertising-supported media is only one way for companies to market to businesses. In addition, many companies also supply training, free samples, and other useful goods and services to potential business customers. We have not been able to find any data on these items, so we do not include them in this paper.

[10] By construction, GDP depends only on final output, so the intermediate outputs should be irrelevant. In practice, the BEA uses expenditures as a proxy for government and nonprofit output. As a result, changing intermediate input prices has the potential to affect measured output prices. For simplicity, we will ignore this aspect of GDP measurement in our paper.

[11] Brynjolfsson and Oh's paper (2012) values free websites, which is not exactly equivalent to advertising-supported websites, but that only explains a portion of the difference.

studies use indirect methods to estimate the consumer utility gained from leisure time spent online. However, this paper is trying to estimate only the cost of producing online media. There are many areas of the economy in which consumer spending on an activity is much lower than total utility for that same activity. For example, sleeping occupies about one-third of total time and provides enormous utility, yet beds represent a very small fraction of consumer spending.

On the other hand, our estimates are consistent with preexisting estimates of the consumer value for high-speed Internet. In 2006, Greenstein and McDevitt (2011a) estimated that U.S. households received $20 billion to $22 billion of value from broadband Internet. In comparison, we estimated that U.S. households enjoyed $7 billion worth of advertising-supported online entertainment in 2006.[12] This $7 billion excludes consumer utility from nonadvertising online activities such as Wikipedia and Skype. It also excludes the value received by self-employed individuals who use residential Internet for business purposes and home owners who use their Internet to research do-it-yourself home repair. We do not know the value of these activities, but it seems plausible that adding them would raise our numbers enough to be in the same ballpark as Greenstein and McDevitt (2011a).

Section 3: Price Indexes for Media and Advertising Viewership

Media services are very difficult to deflate properly. One issue is that media users constantly demand original content, so we cannot track the cost of producing the exact same website over time. In addition, media services are nonrival goods with poorly defined units of output. For example, a blogger might switch from writing a few long posts to writing many short tweets. Is this change an increase or decrease in total output? Finally, media quality depends on the quality of the durable goods used in the production of the entertainment services, and that quality has risen dramatically. This applies to both the production of entertainment services by media publishers and the production of entertainment services in the home. For example, the quality of Google searches is enhanced by improvements in the cloud hardware and software used by Google in conducting the searches as well as by the growing availability of websites to be

[12] Consumer utility from viewing websites = (Cost of advertising-supported entertainment) + (Consumer surplus from websites) – (Disutility from viewing ads). Our methodology measures neither the consumer surplus from websites nor the disutility from viewing ads. For simplicity, we assume they cancel out.

searched. Similarly, high-definition televisions and monitors enhance the quality of videos and television programs being watched, and, indeed, the videos have higher production values to take advantage of the improved receiver quality.

The price indexes presented in Figures 9–12 do not account for network effects, positive externalities from media consumption, or other media-specific factors. We believe that these factors probably raise online media quality over time and, therefore, lower quality-adjusted prices. As a result, the inflation rates shown for online media should be seen as being on the upper end of the true inflation rate. On the other hand, the size and direction of the bias for other media categories are harder to measure. In addition, the experimental methodology developed in this paper may have secondary implications for price measures for media that are partially advertising supported and partially paid by users. These implications are a topic for future research. For now, we hold all other price indexes in the industry-level production account fixed.

Prices for Online Media

We start by constructing a price index for online media. The three main inputs to online media are software, computers to run the software, and everything else. For example, search engines start out with complex algorithms to optimize the search process. They then run these algorithms on server farms every time someone enters a query. In addition to these direct costs, online media companies also have overhead costs such as salespeople, utilities, and rent. We were unable to find price indexes specific to the software used by online media companies, the computers used to process requests, or their overhead costs. Instead, we use the BEA's price indexes for prepackaged software (BEA Table 5.6.4, line 3) as a proxy for software costs, a price index for cloud-computing services reported in Byrne and Corrado (2016) as a proxy for computer costs, and BEA's price index for personal consumption services (BEA Table 1.1.4, line 6) as a proxy for overhead costs.

Figure 9 shows the combined price index for online media together with the individual component prices.[13] We find that online media prices have fallen approximately 12% per year.

[13] Our combined price index is a simple geometric mean with equal weights for each component. The combined price index is very sensitive to the weights assigned to each component and the averaging technique.

Most of this decline is due to plummeting cloud-computing prices; the small price declines for software mostly cancel out the small price increases for services overhead. At first glance, our price index appears to assume zero productivity growth in the online media industry. In fact, we assume that modern computer programmers are much more productive at writing software than they were in 1995. This rising productivity has allowed prepackaged software prices to fall 4% annually even as programmer wages have risen. Similarly, data processing companies have become much more productive at using their servers to provide computing services. This productivity increase has allowed cloud-computing prices to fall faster than prices for business computer investment. We assume that programmers producing own-account software for online media companies and servers producing own-account cloud-computing services for online media companies have enjoyed similar productivity gains. Therefore, output prices for online media fall faster than average input costs.

Prices for Print Newspaper and Magazines

Next, we construct a price index that covers both newspapers and magazines. Book publishers produce a product very similar to newspapers; therefore, wholesale book prices are a good proxy for the costs of writing, editing, printing, and delivering newspapers. We use the BEA's price index for book originals (BEA Table 5.6.4, line 25) as a proxy for all these costs. As with consumer software, this is an output price and, therefore, includes some productivity growth over time. However, newspapers and magazines generally require more outside research than books do. We were not able to find any data specific to journalist research costs, but we believe that these costs are related to communication technology. Before 1995, journalists did most of their research over the phone, so phone costs are a good proxy for nonlabor research costs. Over the past few decades, journalists have been gradually shifting to online research; therefore, the online media price index developed in Figure 9 is a good proxy for nonlabor research costs.

Figure 10 shows the combined price index for print media together with the individual component prices.[14] Unlike online media, newspaper prices have been rising steadily over time.

[14] Our combined price index is a weighted geometric mean, with an 85% weight on books. The weight for online media starts at 0.5% in 1995 and gradually rises to 10% in 2014. Phone prices are weighted with the residual.

It is true that cell phones and search engines make reporting much easier and more efficient. However, the basic job of writing and then editing a story has not changed much, so there is little increase in labor productivity. Furthermore, wages for white collar professionals such as authors and journalists have risen substantially over time. The net impact is steady price growth for print media production.

Prices for Cable Television

We next construct a price index for cable television. Unlike the earlier price indexes, we could not find proxy indexes for advertising-supported television. It is true that BEA tracks prices for CDs, DVDs, cable television, movie tickets, and other products that seem closely related to advertising-supported television. However, those four price indexes display very different growth rates in the published data. Because of this discrepancy, we are reluctant to use any of those four price indexes in this paper. As an alternative, we will use input prices as a proxy for output prices. The input-based price index implicitly assumes that television networks have not become more productive at delivering their media content over time. Despite this assumption, measured productivity for television networks could rise if they become more productive at producing television programs over time.

The technology for cable television programs is relatively simple. They start out by buying or creating media content. Next, they deliver that content to subscribers using cables, satellites, or other transmission technology. We identify three separate input prices to track: (1) nonsports programming costs, (2) sports programming costs, and (3) program transmission equipment. It is relatively easy to find proxy price indexes for the first two inputs. We use the BEA's preexisting price index for long-lived television programs (BEA Table 5.6.4, line 24) as a price index for nonsports shows and the BEA's price index for sports tickets as a price index for sports programming (BEA Table 2.4.4U, line 209). Tracking prices from transmission equipment is slightly harder. In recent years, the Bureau of Labor Statistics (BLS) has published a Producer Price Index for radio and television equipment manufacturing. However, that price index only covers a few years. In addition, Byrne and Corrado (2015) strongly challenges the BLS's price indexes for communications equipment. In this paper, we use their price index (Byrne and

Corrado's Table B.7, column "Total Transmission Equipment") from 1974 until 2009. Byrne and Corrado's price index for transmission equipment tracks reasonably well with BEA's existing price index for television sets (BEA Table 2.4.4U, line 39). We use this price index to extrapolate prices for transmission equipment back to 1959.[15]

Figure 8 shows the combined price index for cable television together with the individual component prices.[16] We find that prices have been almost flat since 1990. This price growth is midway between the price declines in Figure 9 and the price increases in Figure 10 Intuitively, cable networks use more computers than print media companies and fewer computers than online media companies.

Prices for Broadcast Radio and Television

Like cable networks, broadcast networks use media content and transmission equipment.[17] However, they have another capital requirement as well. Broadcasters need spectrum to transmit their content from the station to users. If they don't have sufficient spectrum, then the television signal may interfere with other users of the airwaves. We have not yet been able to find any data on programming costs for radio programs. For now, we assume that radio programming costs track television programming costs.

Unfortunately, it is very difficult to track prices for radio or television spectrum. The first paper discussing spectrum sales was published in 1959 (Coase). But the Federal Communications Commission did not start auctioning spectrum until the 1990s and even now does not allocate spectrum entirely based on market demand. We have explored using the spectrum price index developed by Wallsten (2013). However, that index does not start until the

[15] Conceptually, the television set is a large part of the viewing experience, and we should include prices for these in our input measure. However, that would add complexity without changing any long-term results.

[16] Our combined price index is a weighted geometric mean, with a 20% weight for sporting events, 70% weight for nonsports programs, and 10% weight for transmission equipment.

[17] When calculating our price index for broadcast television, we use Byrne and Corrado's price index for broadcast equipment (their Table B.3, "Radio Station Equip. ex. Satellite") instead of the price index for cable. According to their paper, the price for broadcast equipment has dropped dramatically since the 1960s but not quite as fast as the price index for cable transmission. The rising relative price may explain why consumers have mostly switched from broadcast television to cable television. In this paper, we use weights of 15% for sports programming, 52.5% for nonsports programs, 7.5% for broadcasting equipment, and 25% for spectrum costs.

1990s, contains very few auctions of radio or television spectrum, and is very noisy. So, there is no preexisting price index that is perfect for our needs.

We construct a new price index for radio spectrum based on reported sale prices for radio stations in "An American Radio Trilogy: 1975 to 2004" (Duncan 2004). After 2004, we use the BEA's preexisting price index for cell phone service (BEA Table 2.4.4U, line 279) as a proxy for both airwave costs and transmission equipment costs. We were not able to find reliable data on spectrum prices before 1975.[18] Before that time, we use average revenue per licensed commercial radio station as a proxy for airwave costs. We were also unable to find data on television spectrum prices. For now, we assume that they track radio spectrum prices.[19] We welcome suggestions to improve our price indexes for spectrum.

Figure 12 shows the combined price index for broadcast media together with the five component prices. We find that prices for spectrum rights grew very rapidly after 1975. As a result, the calculated price index for broadcast television grew much faster than the price index for cable television.

As a robustness test, we also considered using quantity data to derive prices. The paper "The Random Long Tail and the Golden Age of Television" (Waldfogel 2016) demonstrates a simple methodology to count television show production. We followed his methodology and created a quantity index based on a simple count of all television shows running in the United States from 1949 onward. Based on this quantity index, we calculate an indirect price index. We find that this indirect price index matches the input-based price index reasonably well.

[18] Duncan's book contains some data on radio station sales between 1970 and 1975, but it does not have ratings data. As a result, we cannot adjust sales for quality. After 1975, the unadjusted and adjusted price indexes display very different growth rates. As a result, we do not believe that the unadjusted price index before 1975 is reliable.

[19] As a robustness test, we explored using the share of households with cable as a proxy for television spectrum value. The basic intuition is that broadcasting equipment is cheaper than wired cable, but the airwaves have limited capacity. So, the networks started out with broadcast and then switched to cable when the airwaves filled up. This proxy produces a very similar price history to the radio auction prices: Spectrum values were low before 1975 and then jumped dramatically over the next 10 years.

Aggregate Changes to Real GDP

Even in our experimental methodology, watching television or surfing the Internet is not a highly paid activity. In 2013, we calculate that viewers received only $0.35 of content per hour of watching television ads. Other categories of ad viewership receive even less content per hour. In contrast, employees earned approximately $31 per hour in 2013 (BLS series CMU10100000000D). Clearly, ad viewership is closer to a leisure activity than it is to a work activity. Nevertheless, Americans spend huge amounts of time consuming media. As a result, the total value of advertising viewership contributed by the viewership sector is not trivial. In this section, we test the impact of advertising-supported entertainment on measured GDP.

Figure 13 recalculates our GDP quantity indexes when "free" entertainment is included in final output. We find that our experimental methodology raises GDP growth from 1998 to 2012 by 0.009% per year. This faster growth occurs despite the drop in the nominal GDP share for consumer entertainment shown in Figure 4. Intuitively, prices for advertising-supported media have been rising much slower than overall GDP prices. These falling relative prices more than compensate for the drop in relative nominals, producing faster real growth for advertising-supported media than overall GDP. As a result, measured GDP growth increases when advertising-supported media are included in final output. The combined change of 0.007% per year can be decomposed into a -0.009% decrease associated with print media, a 0.002% decrease associated with broadcast media, a 0.010% increase associated with cable television, and a 0.009% increase associated with online media. Before 1998, our experimental methodology has even less impact on long-term GDP growth rates. Advertising-supported media may be important to consumer welfare. But it is not a new source of economic activity that only arose in 1998. As a result, including advertising-supported media in final demand does not change the overall trajectory of GDP growth much.

It is important to note that the real GDP numbers calculated do not include the consumer surplus from advertising-supported media. An interesting measure of consumer surplus was conducted by Noll et al. (1973). They examine how much viewers were willing to pay for access to the three major television networks in areas of the U.S. outside the broadcast range of one to three of these networks in 1969 (these are payments for no-frills community cable television.) This permits them to estimate that the willingness to pay of U.S. television viewers was close to

$20 billion, or some 10 times as much as the entertainment payments of television advertisers. This suggests that consumers would be willing to pay up to $0.07 an hour to watch advertising-supported television networks. This is substantially higher than the $0.007 per hour that media companies spent on content in 1969. This large difference is one way of interpreting the discrepancy between our estimate of advertising-supported media values with the estimate of Brynjolfsson and Oh (2012).

Quantity Indexes for Advertising Viewership

If there was only interest in real GDP, Figure 13 would be enough to fully measure the impact of free media on the economy. However, most policymakers and researchers are interested in decomposing real GDP growth into the component parts of TFP growth for individual industries, quantity growth of capital, quantity growth of labor, and quantity growth of other inputs. Holding real media output fixed, our experimental methodology treats more Internet surfing as an increase in inputs and, therefore, a reduction in TFP for the media industry. For other industries, more Internet surfing is considered an increase in gross output and, therefore, an increase in TFP. The intuition for this is that nonmedia companies use advertising-supported business information as an input. Ad viewership is the implicit payment for that "free" business information so it is counted as an output.

We will calculate advertising viewership quantities based on time use. First, we estimate time spent by media category from 1929 to 2013. We then combine that time use data with the nominal advertising data shown in Figure 1 and calculate nominal prices per unit of time. This indirect calculation requires the strong assumption that the quality of advertising viewership has been constant over time.[20] Appendix B contains much more detail on how we measure time use for each media category. We welcome suggestions for more data on time use or better proxies for the quantity and quality of advertising viewership between 1929 and 2013.

Figure 14 shows quantity indexes for advertising viewership from 1929 to 2013. Since 1950, we find that advertising viewership has grown much faster than overall population. That increase is partially due to increased media time per capita. But individuals are also consuming

[20] This does not mean that advertising technology has been fixed over time. Rather, improvements in the technology for ad blocking may be canceled out by improvements in the technology for ad deliver. For example, DVRs can be thwarted by ads at the bottom of a football game. The net effect of the arms race is assumed to be zero.

more advertising per unit of media consumption. The change was most dramatic for television viewers. Between 1950 and 2000, advertising slots increased from 15% to 30% of network time. The combined result is a huge increase in advertising exposure per person. If advertising viewership had remained constant over time, then measured prices for advertising viewership would rise much slower.

Section 4. Real Output, Real Input, and Productivity by Industry

Recalculating Total Factor Productivity Using Our Experimental Treatment for "Free" Online Media

This section calculates industry-level statistics for each of the 63 business sector industry categories tracked by BEA and BLS in their joint production accounts. Because there are so many industries, it is not feasible to show each one separately. Instead, we split the 63 industries between media companies and all other industries in the business sector. We then show how our experimental methodology impacts each category.[21]

Figure 15 shows how our experimental methodology changes measured TFP. We find that measured TFP for media companies rises, raising business sector TFP growth by 0.011% per year. Internet publishing companies (NAICS] 518 and 519) contribute the lion's share of the TFP increase, but newspaper publishers also produce significant quantities of online media and contribute to the business sector TFP increase. Measured TFP for the rest of the business sector falls, lowering aggregate TFP growth by 0.005% per year.[22] The net effect is a combined TFP

[21] To make our TFP numbers more comparable with the existing literature, we treat the household viewership sector as an entirely new industry. This new industry is not included in the 63 industry categories tracked in our calculation. We also exclude the government sector. Because of this focus, our TFP numbers only track private sector business and are not representative of the entire economy. Our exact TFP calculations are based on internal numbers collected by BEA for research purposes. These numbers do not always match perfectly with the joint BLS–BEA production accounts. However, the differences are typically very small and do not impact the revisions to TFP shown in this paper.

[22] At first glance, it seems surprising that new technology such as Waze is associated with lower TFP. However, Figure 12 does not show actual TFP but rather the revision to measured TFP caused by our experimental methodology. For example, a restaurant might use Waze to get delivery directions. BEA's current TFP statistics treat an improvement in the Waze directions as an increase in TFP for the restaurant industry. Our experimental methodology shifts the better directions from the restaurant industry to Silicon Valley, lowering measured TFP for restaurants and raising measured TFP for Silicon Valley.

increase of only 0.007% per year. This change is not nearly enough to reverse the recent productivity slowdown.

At first glance, the numbers in Figure 15 appear implausibly small. Figure 13 shows that real GDP growth increases by 0.009% per year when online entertainment is included in the final output. Yet, business sector TFP growth increases by only one-half of that amount. These seemingly contradictory results can be explained by advertising viewership. Between 2007 and 2014, time spent online increased 80%. This increased time partially cancels out the increase in real media output. Conceptually, the real quantity of media received per hour online is roughly comparable with real wages. When labor hours increase, real GDP increases faster than real wages. Similarly, real online media output can increase faster than TFP in the online media industry.

The revisions to measured TFP shown in Figure 15 are much smaller than predicted by popular literature (Ito 2013, Aeppel 2015). The main cause of this difference is how we weight "free" apps in our TFP numbers. The standard productivity formula assigns weights in proportion to gross output. Even in 2013, online media accounts for a very small share of the overall economy. Accordingly, higher TFP growth for Internet publishers has little effect on aggregate TFP growth. In contrast, the popular literature assigns weights in proportion to time use. By 2013, Americans spent more than 20% of their time online. If we used that weight to value free apps, aggregate TFP growth would increase dramatically.

Recalculating Total Factor Productivity Using Our Experimental Treatment for "Free" Online Media with Quality Growth

The business sector TFP numbers in Figure 15 are based on the price index for online media developed in Figure 9. As discussed earlier, the price index in Figure 9 does not include any quality adjustment for network effects, user-generated content, or factors unique to Silicon Valley. In this section, we explore using bytes of data to proxy for these quality issues. Between 1998 and 2012, Cisco reports that Internet traffic grew 79% per year. This growth rate continued throughout the dot.com bubble and bust, the Great Recession, and the recent recovery. Based on

that quantity growth, we calculated that quality-adjusted prices might have fallen as fast as 31% per year. As a robustness test, we will recalculate business sector TFP using that price index.

Figure 16 shows how the quality-adjusted prices change measured TFP growth. Between 1998 and 2012, measured TFP growth now increases by 0.024% per year. This is five times the effect calculated in Figure 12, suggesting that quality growth may be very important when measuring advertising-supported online media. However, even a TFP increase of 0.024% per year is not enough to reverse the recent productivity slowdown (Syverson 2016).

Recalculating Total Factor Productivity Using Our Experimental Treatment for Print Media, Broadcast Media, and Cable Television

Even though the Internet receives the most popular attention, it is not the largest category of advertising-supported media. Figure 4 shows that online advertising is still much lower than television advertising, and it has only recently surpassed print advertising. Similar to online media, our experimental methodology includes free print, radio, and television media in consumer entertainment and business information. We can use the same TFP formulas developed earlier for online media to calculate how these media categories might change measured TFP.

Figure 17 shows the impact of print media. We find that measured TFP growth rises by 0.004% per year before 1998 and falls by 0.004% per year after 1998. These changes are not trivial, but they are smaller than the reductions in real GDP growth shown in Figure 10. Most of the reduction in real GDP growth shown in Figure 10 is caused by a reduction in the quantity of advertising readership. Similar to any other input, changes in advertising readership have no direct effect on measured TFP. These small effects may be explainable by the maturity of the print industry. Newspaper production technology has not changed much between 1948 and 2012.

Figure 18 shows the impact of broadcast radio and television media. Between 1948 and 1965, we find that measured TFP growth falls by 0.006% per year. After 1965, measured TFP growth rises slightly. Most of the early TFP decline is probably associated with changing radio genres. Since 1965, approximately 80% of radio shows have been music oriented. Most radio music listeners are focused on activities such as driving or exercising and generally pay very

little attention to the radio program. Before 1965, most radio programs were soap operas, quiz shows, or other genres that required more attention. Holding everything else fixed, advertisers probably prefer listeners who are paying more attention. Therefore, the shift from soap operas to music programs can be seen as a quality decrease in radio listenership. It is possible that measured TFP growth would fall less or even rise if we adjusted our quantity index for listenership quality. This period also coincided with a government crackdown on radio payola, which might also impact measured TFP. This is a topic for future research.

Figure 16 shows the impact of cable television. Between 1975 and 2012, we find that aggregate measured TFP growth rises by 0.006% per year. This is almost as large as the 0.007% increase in TFP growth from online media shown in Figure 12. In recent decades, the dramatic growth in online media has received the lion's share of academic and policymaker attention, but the growth in cable television also has large benefits to consumers. Recent research shows that the number of television shows produced each year has exploded without any apparent decline in their average quality (Waldfogel 2016). This increased variety is particularly beneficial for consumers with tastes different from the norm.

Other Effects of the Media Industry on Measured Productivity

In theory, the joint BLS–BEA production accounts already capture everything except advertising-supported media. For example, cable subscriptions are already in PCE when purchased by consumers and already intermediate inputs when purchased by businesses. As a result, measured TFP should include the dramatic increase in the quality of media over time. In practice, quality improvement is sometimes hard to measure, and BEA's existing productivity statistics may underestimate real output growth for some information technology products and services.

Researchers disagree on how completely BEA's current price indexes capture quality change in the goods and services used to access media. In recent years, most research has focused on Internet access. In the period from 2004 to 2009, Greenstein and McDevitt (2011a, b) take two different routes to measure the price of broadband services. Both studies find very modest declines in quality-adjusted prices, on the order of 2% annually. These studies imply that

the implied willingness to pay for broadband speeds and rapid increases in data downloads is not very high. However, these studies do not take into consideration the heterogeneity of broadband customers, which appears to be very high. This heterogeneity can be seen in the work of Nevo et al. (2015), which uses hour-by-hour Internet data usage to estimate some 50 types of users, taking advantage of usage-based plan differences across different plans. These usage-based plans have different download speeds, covered by a fixed fee with a monthly download allowance and a linear price for downloads beyond the allowance. They calculate that consumer surplus for existing broadband customers is $85 a month, but they pay $70 a month. They further estimated that the adoption of Google Fiber (which has 14 times the download speed of the 2011 broadband average in the study) at $70 a month (the price offered in Kansas City) would increase consumer surplus to more than $200 a month while tripling downloads.

Exactly how far quality-adjusted prices should fall is a difficult question to answer. An important issue is that the willingness to pay at a point in time is affected by the rapid change in the uses and usefulness of applications. For example, HD televisions provide very little value for television shows filmed in low resolution but enormous value for television shows filmed in high resolution. Similarly, smartphones equipped with GPS technology have become much more useful with the introduction of location-based apps such as Waze and Uber.

Broadband Internet, televisions, and other media access spending accounts for a much larger share of GDP than advertising-supported media. According to the BEA's published statistics, consumer out-of-pocket payments accounted for approximately 2% of GDP in 2012. In comparison, we estimate that advertising-supported consumer entertainment accounted for only 0.5% of GDP. Results are less detailed but are qualitatively similar for media usage by businesses. It is possible that the revision to measured TFP from new price indexes for broadband Internet services, television sets, or other media access technologies could dwarf the revisions to TFP shown in Figures 12 to 14. However, new price indexes for telecommunications, televisions, and other media services are not directly related to the conceptual question of how to track advertising-supported media in GDP. After all, research on hedonic computer prices started long before the Internet (Triplett 1989). This paper focuses on the advertising-supported media industry and does not attempt to track every related good or service.

Section 5. Network Effects and Organizational Capital

URL: Ubiquity Now, Revenue Later

The previous sections have focused on media companies that rely on advertisers to subsidize media content. In this section, we explore Internet startups such as Uber and Amazon that offer their goods and services below cost temporarily. A key feature of these firms is that they have positive user network externalities; that is, when more consumers use these sites, each individual consumer benefits more from his or her own use. These network externalities are especially important for platform services such as Uber and Airbnb that are the intermediates between users and providers. But they also apply to Internet companies such as Amazon that offer goods and services directly. Sullivan (2016) provides a recent discussion of the importance of fast growth for Internet companies. In Silicon Valley, this is known as the URL (ubiquity now, revenues later) business model. Early on, many Internet companies rely on venture capital funding to subsidize their products so they can grow fast and achieve network externalities more quickly. In this section, we explore accounting for venture capital-supported Internet companies that do not earn advertising money.

This poses an immediate challenge for output measurement.[23] The BEA's current GDP statistics already include investment in research and design, software, and entertainment originals. If these categories of intangible capital were the only components to creating a user network, then the current GDP statistics would measure network capital already. In fact, companies also invest in marketing, customer contact, business know-how, and other organization capital. In this section, we explore how these categories of intangible capital might change the published GDP statistics. While firms are rapidly growing, building out their brands and market reach, they are expending more resources than they will need to when they have reached optimal size. One obvious example is Uber, which has been growing rapidly and in the process has had a lot of expenditures in building intangible assets. It has invested in much more than its physical plant and equipment; as a consequence, because expenditures in intangible

[23] Another concern is the problem of price measurement, to the extent that the utility of the service may not be constant from period to period. Rather, quality increases over time: Demand shifts outward over time, referring back to the figures in Section 1, generating increases in consumer surplus that will not be well captured in standard price measures (see Nakamura 2014 for a discussion). Unfortunately, we are not aware of any method that would permit us to capture this type of utility gain.

assets are generally expensed rather than capitalized, it has had relatively low profitability (and, despite this, a very high equity market value).

We will argue that customer reviews and other user-generated content account for a large share of the network effects associated with the URL business model, and, therefore, even nonmedia companies are partially media companies. The barter transaction associated with customer reviews is conceptually similar to the barter transaction associated with advertising viewership: Users pay less out of pocket in return for providing something useful. For example, Amazon has accumulated 35 million product reviews over 18 years.[24] These reviews would have cost billions for Amazon to write in house. Even when customers do not actively review products, their decisions on what to buy, where to click, and whether to seek a refund create implicit reviews for products and services. Accordingly, we can use the same experimental methodology developed earlier for advertising-supported media to recalculate GDP and TFP for nonmedia Internet startups.[25]

Measuring the Value of User-Generated Content

The expenses of a firm that has pursued the URL model represent the expenditures the firm has made that might be considered to have been supported by the expectation of future revenues. The equity value of the firm might represent the expected value of those future revenues; that is, the discounted present value of the flow of producer surplus that future sales are expected to generate. As such, the equity value should have some relationship to the past value received by consumers during the period of growth of the firm's network. Under free entry, the ex ante expenses and the ex ante equity value should be equal across the set of firms competing to enter

[24] Data up until March 2013 are available at https://snap.stanford.edu/data/web-Amazon.html.

[25] The Internet allows consumers to participate in expressive activities such as posting photographs, videos, political statements, product critiques, and artwork. These contributions blur the line between what is production and what is consumption. As production, they can be viewed as gifts to other individuals or, as Norman Mailer said, "advertisements for myself." Before the Internet, individuals often participated in expressive activities with friends and family but were not able to share their output worldwide, and national accounts have generally excluded these household activities from GDP.

the market. In turn, overall ex ante and ex post equity value also should be equal. This includes the expenses of the firms that fail in their efforts to establish a network.

However, it is possible that an entrant may be able to exploit a uniquely valuable entry point that results in quick establishment of a monopoly, as Facebook did in its base at Harvard College, with its unique prestige. Such an early monopoly may break the equality between ex ante expenses and ex ante equity value. And the equity value will include the expected producer surplus of investments yet to be made because the market value of a strong user base may well enable investments that have positive net present value.

Another difficulty for the U.S. national income and product accounts is that the advertising base for an Internet firm may be the entire world, but we seek to measure the consumer gains to U.S. domestic households.

With these caveats, two measures of the economic value to consuming households of these free media websites might be (1) the expenditures for setting them up, one measure of which is the money raised from investors plus the expected future value of equity shares that reward the site's employees, and (2) the equity value of the firm. Customer reviews represent a significant portion of the network effects that create firm equity. Therefore, we can use firm equity as an upper bound on the total output of customer reviews.

Leading examples of U.S. social networks include Google, Facebook, Yahoo!, LinkedIn, and Twitter. Together, these five firms had an equity value of more than $650 billion in mid-2015, almost all of it generated in the past decade; only Google had a significant market value 10 years ago ($50 billion in mid-2005). Thus, these firms alone added $600 billion — $60 billion a year — in expected future value over the past decade. This equity value is much larger than the advertising revenue earned by the firms over the same time period.

On top of this, the private valuation of the 131 startup private companies that had an individual valuation of $1 billion or more worldwide, based on their financing round valuations, was about $485 billion, according to KPMG CB Insights (2015). Of that total, the U.S.-based firms amount to roughly $300 billion. Assuming this investment was created over the past decade, this would add another $30 billion a year to this investment. The case can be made based on these equity values that URL investments subsidize as much expenditures on behalf of

consumers as are currently directly funded by Internet advertising if we sum up the roughly $1 trillion in equity value created. However, national accounting procedures depend on measuring flows of economic activity rather than accumulations of equity value. We, therefore, turn to measures of the funding of Internet startups to measure the potential size of URL contributions to GDP.

Data from CB Insights on venture capital funding of U.S. startups from 2011 to the third quarter of 2015 totaled $218.5 billion (covering some 21,000 deals), or $46 billion a year for 4.75 years. These data do not include the additional funding raised through initial public offerings, but again, this includes many firms that do not expect to pursue an advertising model.

To obtain a longer time series, we go to Standard & Poor's Global Market Intelligence data service. We further limit the data to private equity funding of Internet firms, in which we included all records, going back to 1990, for private placements in the U.S. in six industries: (1) application software, (2) data processing and outsourced services, (3) Internet retail, (4) Internet software and services, (5) online gaming operations, and (6) online ticketing agencies. Notably, we see that in the Internet bubble era of 1999–2001, there was a sudden burst of private placement investments, amounting in a total of $84.5 billion in those three years. By comparison, in the period 2013–2015, we have recorded a total of $75.4 billion. Thus, the current episode does not imply an acceleration with respect to the earlier one in 1999–2001. On the other hand, it is possible that the current episode may prove to have more solid foundations.

Table 1 shows our annual numbers for private equity funding of Internet firms. The streams of private placement investment flows underlying the expenditures made by these Internet firms appear to be considerably less than this, more like $10 billion to $40 billion at most. Moreover, although there has been acceleration in this spending over the past few years, investments made were larger during the Internet bubble of 2000.

Figure 20 shows how measured TFP would change if venture capital-supported customer reviews were valued using the same methodology we used earlier for advertising-supported media.[26] Between 1998 and 2012, the experimental methodology increases the average TFP

[26] For this graph, we use our preexisting price index for online media to value nonmedia Internet products and services and our preexisting price index for advertising viewership to value customer reviews. Just as with advertising viewership, we focus on the short-term barter transaction and do not consider capital services.

growth by 0.003% per year. This average masks enormous variation over time. Between 1998 and 2000, measured TFP growth increases 0.03% per year. Measured TFP growth then falls with the dot.com bust and slowly recovers. As a result, accounting for Internet network effects actually makes the slowdown in TFP growth during the 2000s worse. Our TFP numbers end in 2012, so they do not include the recent acceleration in equity investment.

Concluding Remarks

The media sector poses a number of difficult questions for the national income accounts and the measurement of productivity. In this paper, we have addressed one narrow question: how to account for advertising-supported media. We show that the Internet is not the first media category to be subsidized by advertising, and many of the measurement issues can be addressed by a simple tweak to the current GDP measurement methodology. We then used our experimental methodology to recalculate GDP and GDP growth.

We found that the experimental method has a minimal impact on measured GDP growth and TFP growth. Between 1929 and 2013, nominal GDP growth rose 0.001%, and real GDP growth fell 0.004%. Between 1948 and 2012, aggregate measured TFP increases by 0.006% per year when we include advertising-supported media in the input-output accounts. The main cause of the stability is that advertising-supported media hovered around 0.5% of nominal GDP from 1929 to 2013. As a result, this category is simply too small to impact aggregate economic statistics much.

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Figure 4: Advertising Revenues Over Time

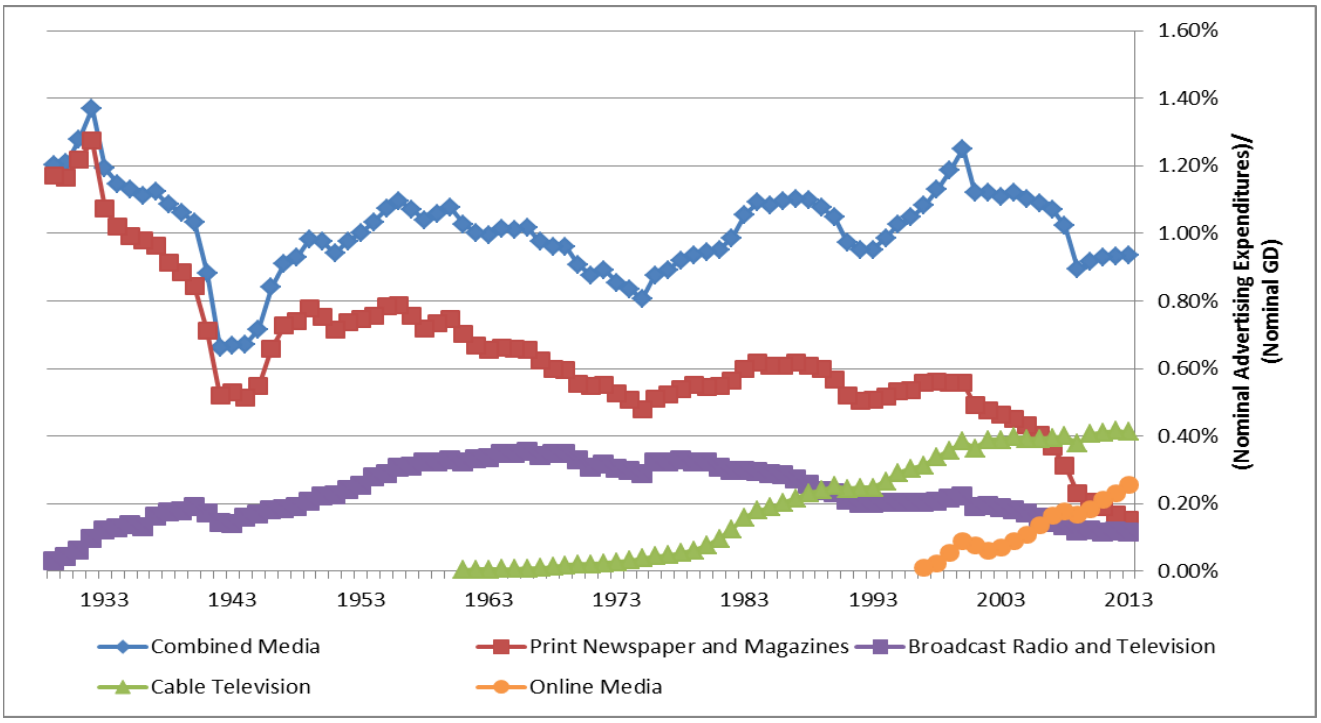

Figure 5: Share of Advertising Revenue Spent on Media Costs

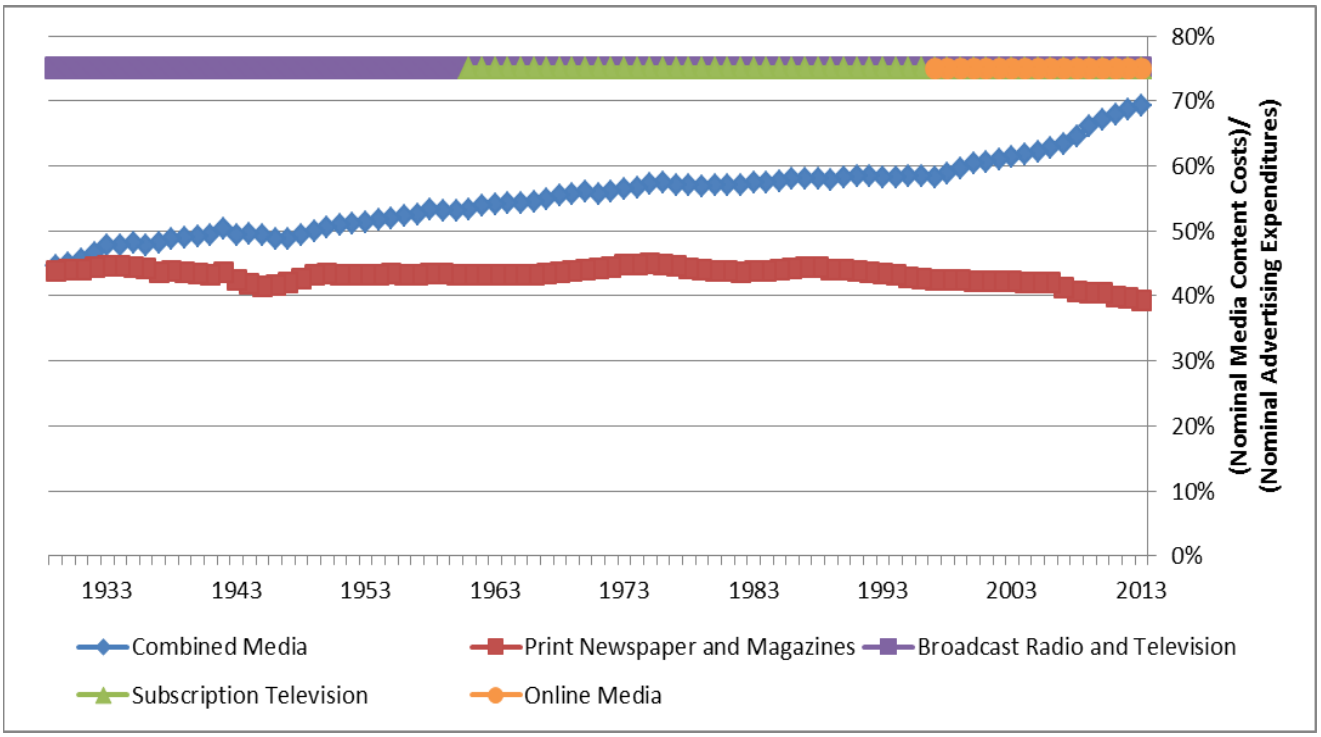

Figure 6: Consumer Entertainment Share of Media

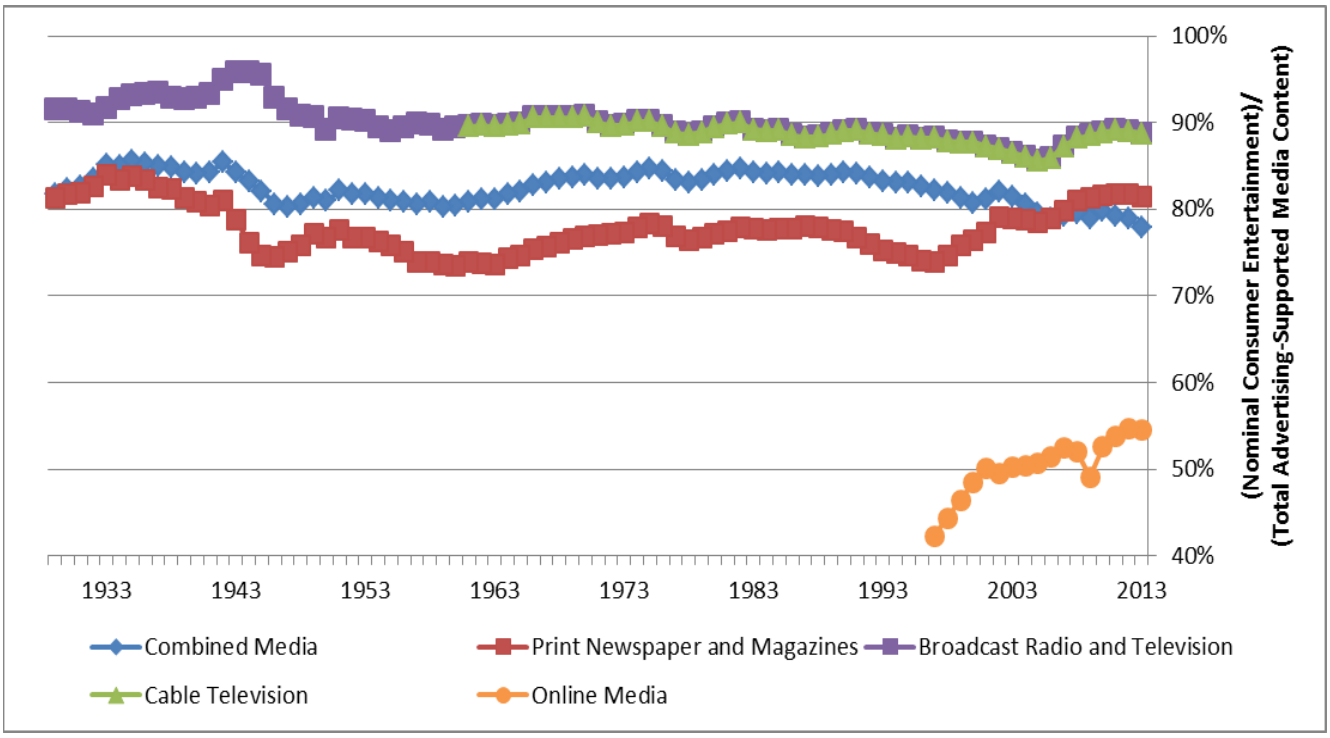

Figure 7: "Free" Consumer Entertainment Over Time

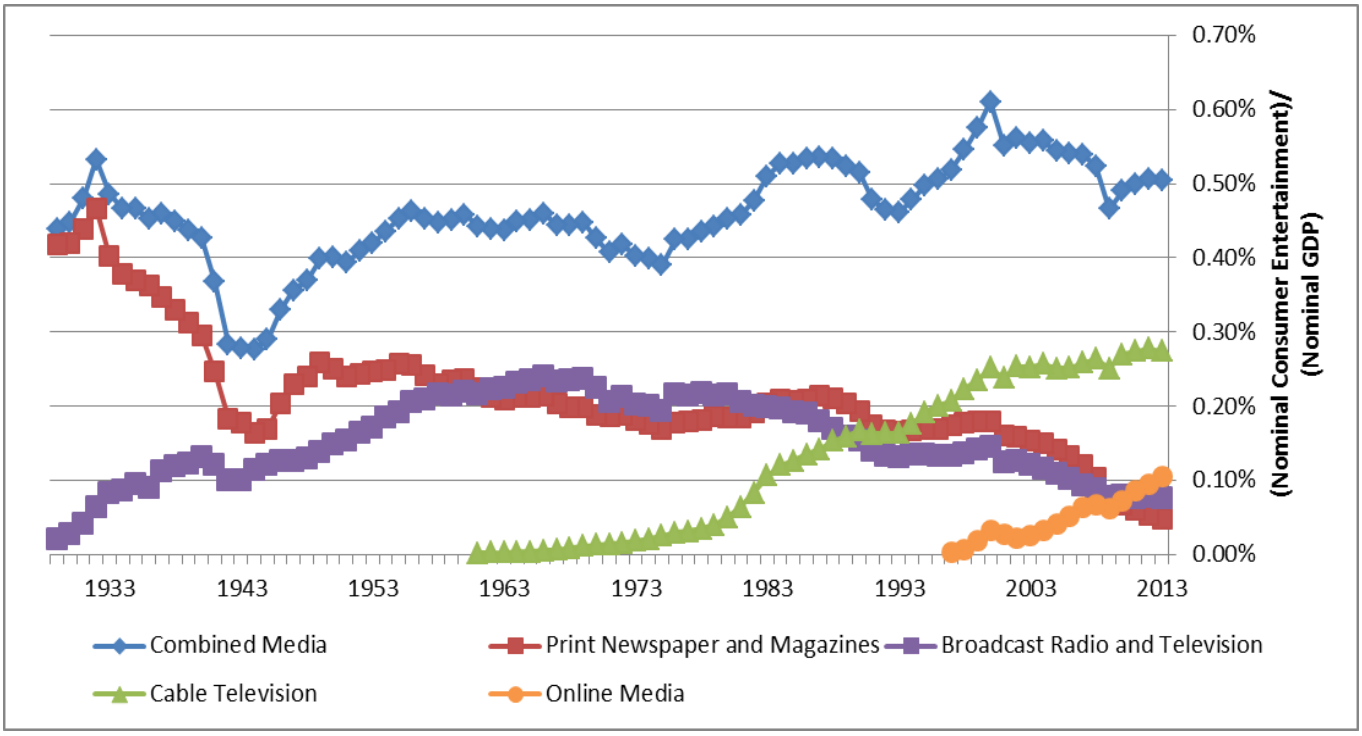

Figure 8: "Free" Business Information Over Time

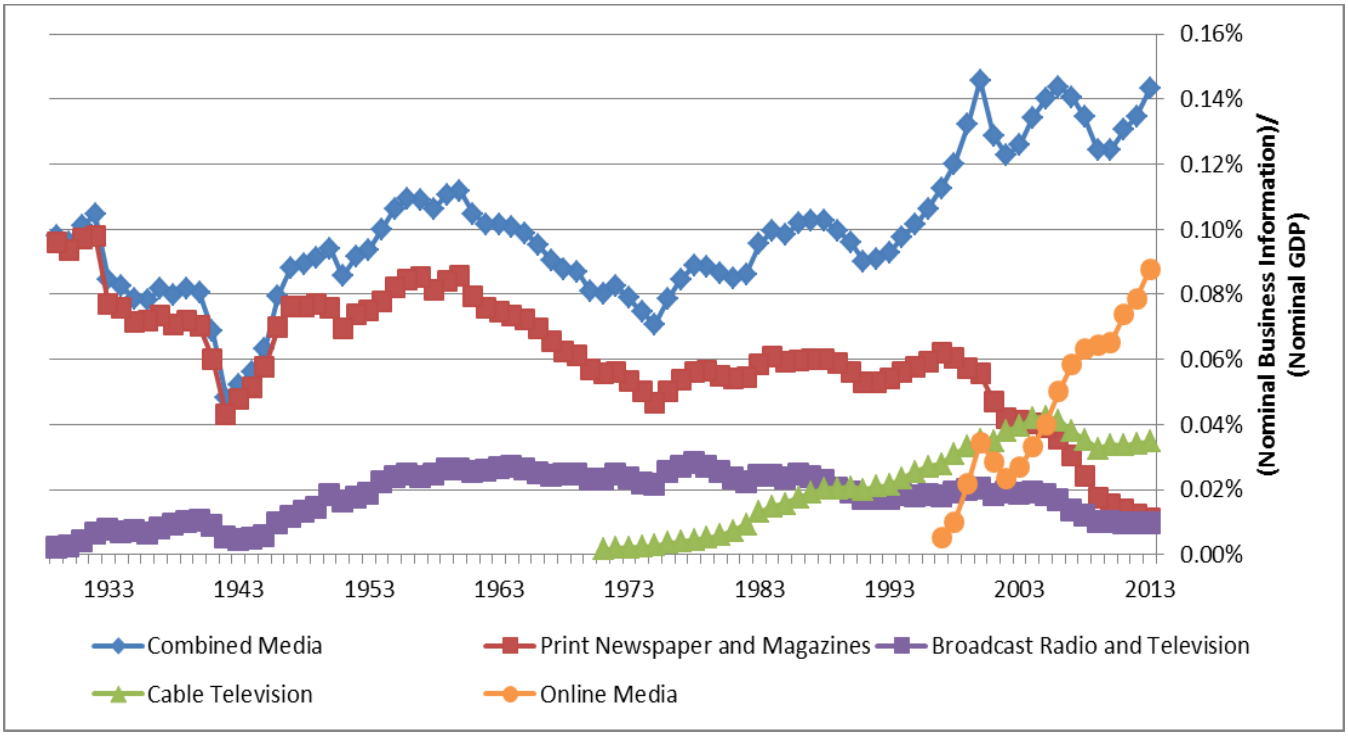

Figure 9: Prices for Online Media

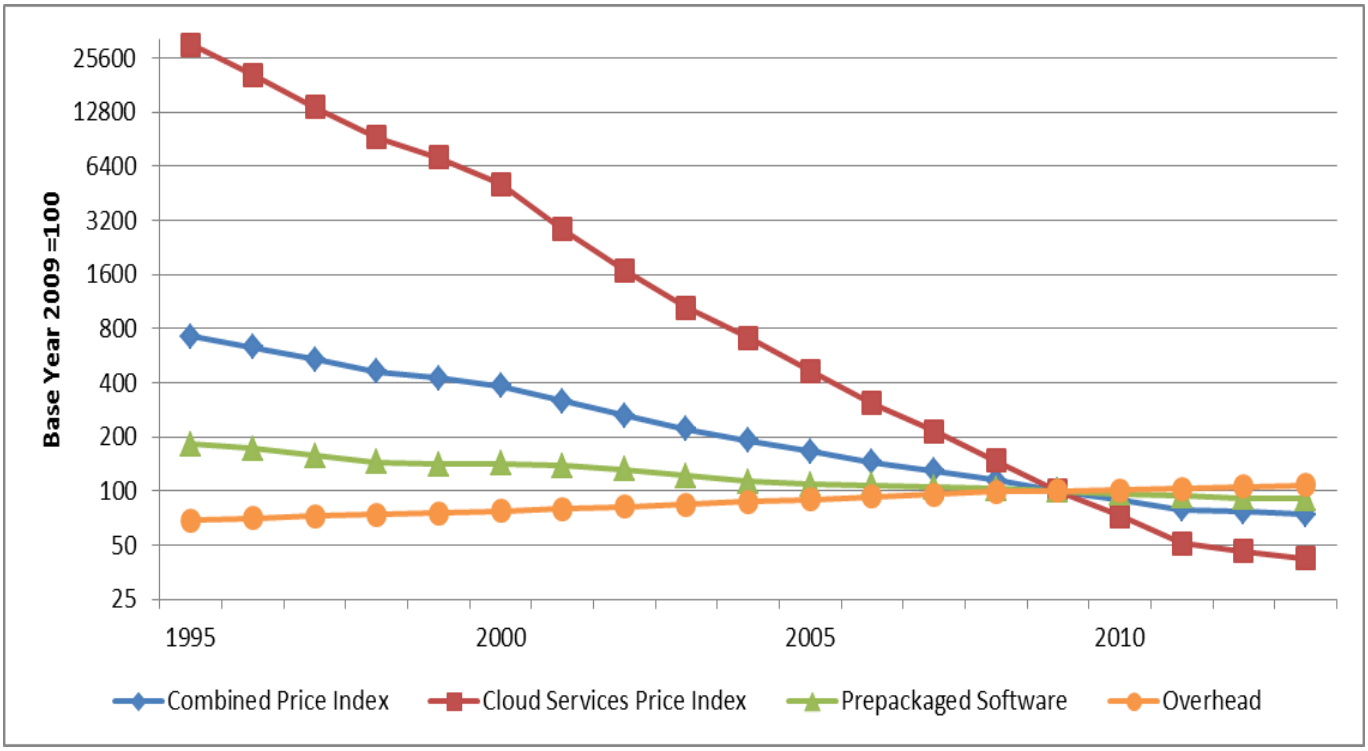

Figure 10: Prices for Print Media

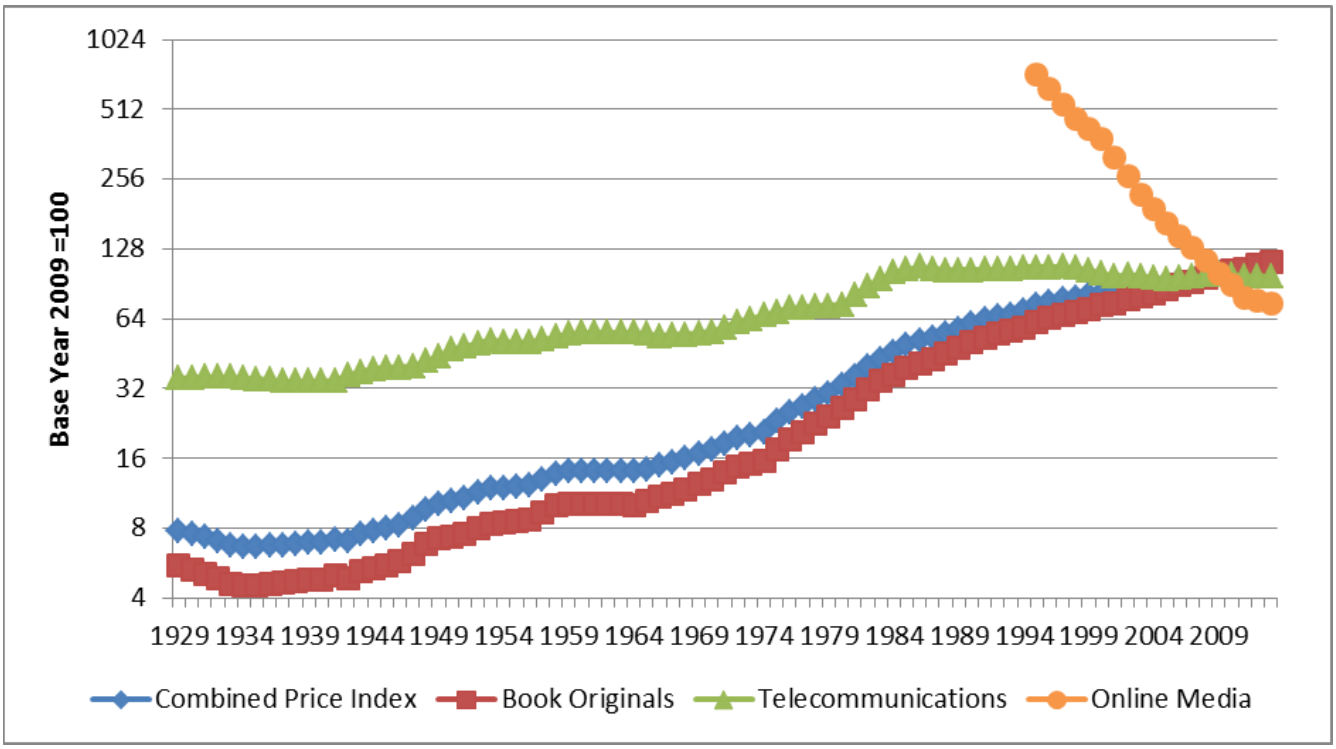

Figure 11: Prices for Cable Television

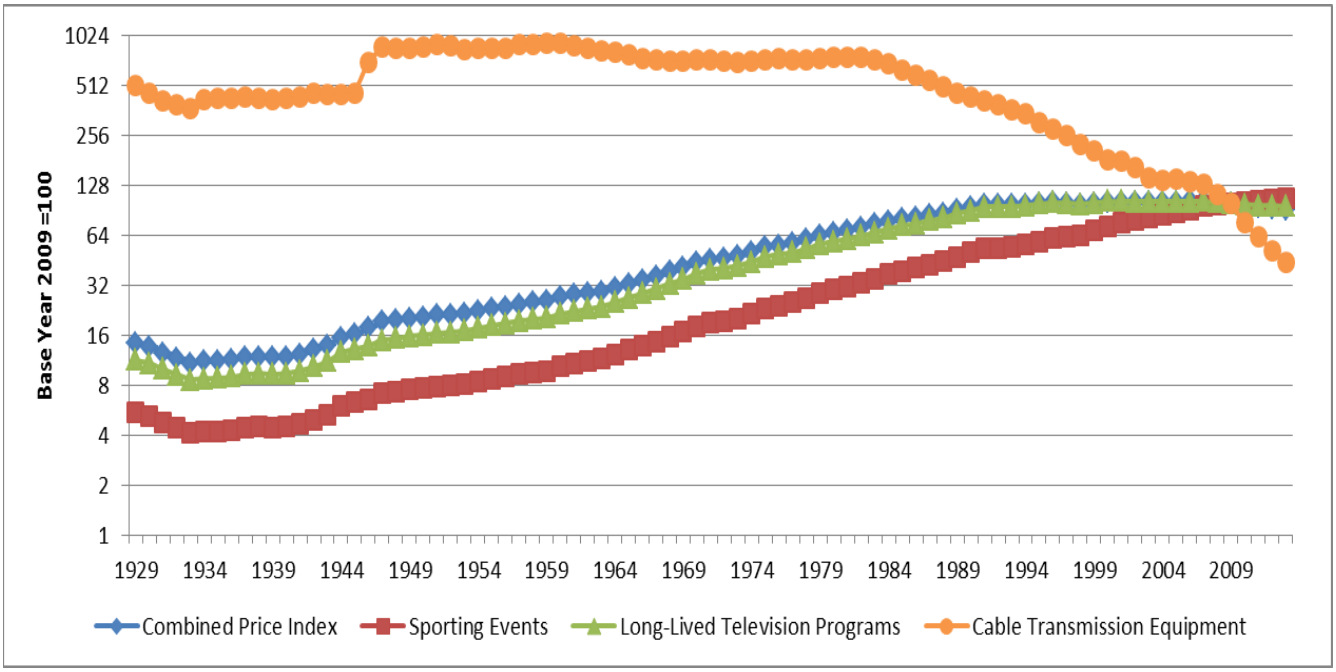

Figure 12: Prices for Broadcast Television and Radio

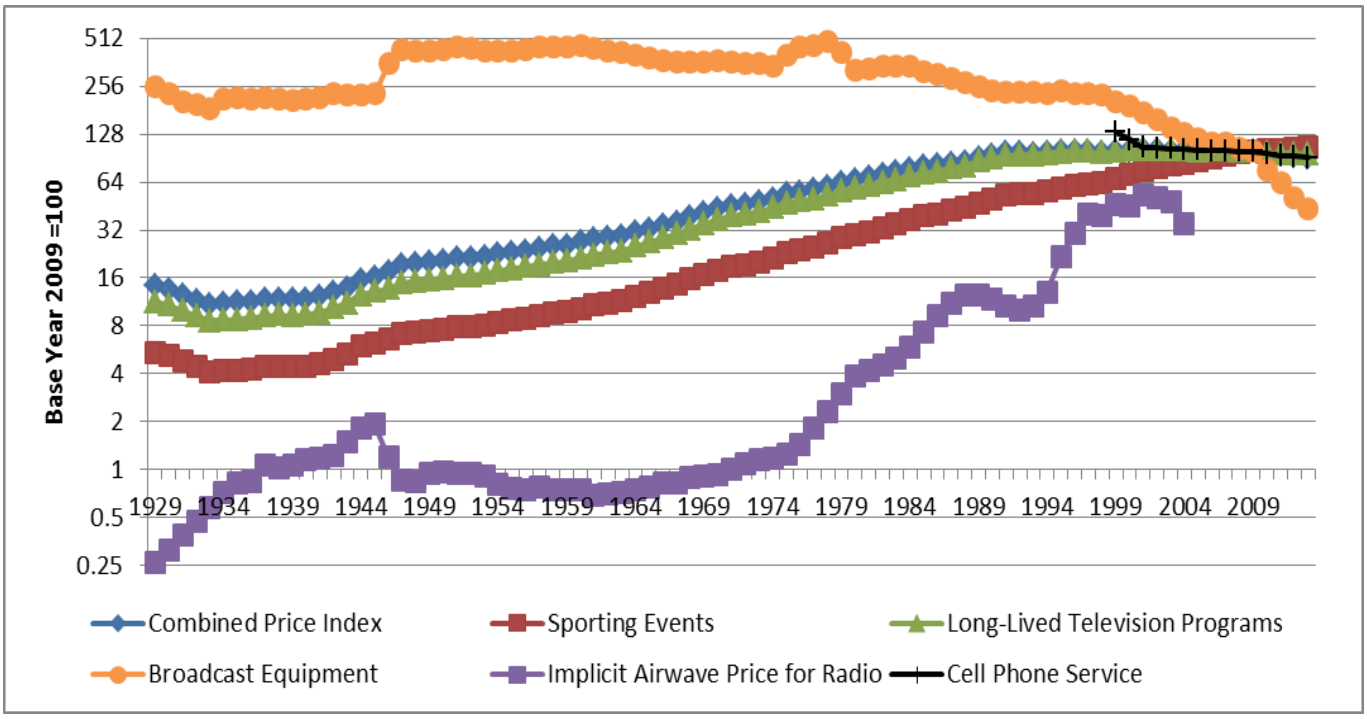

Figure 13: Change in GDP Quantities from "Free" Media

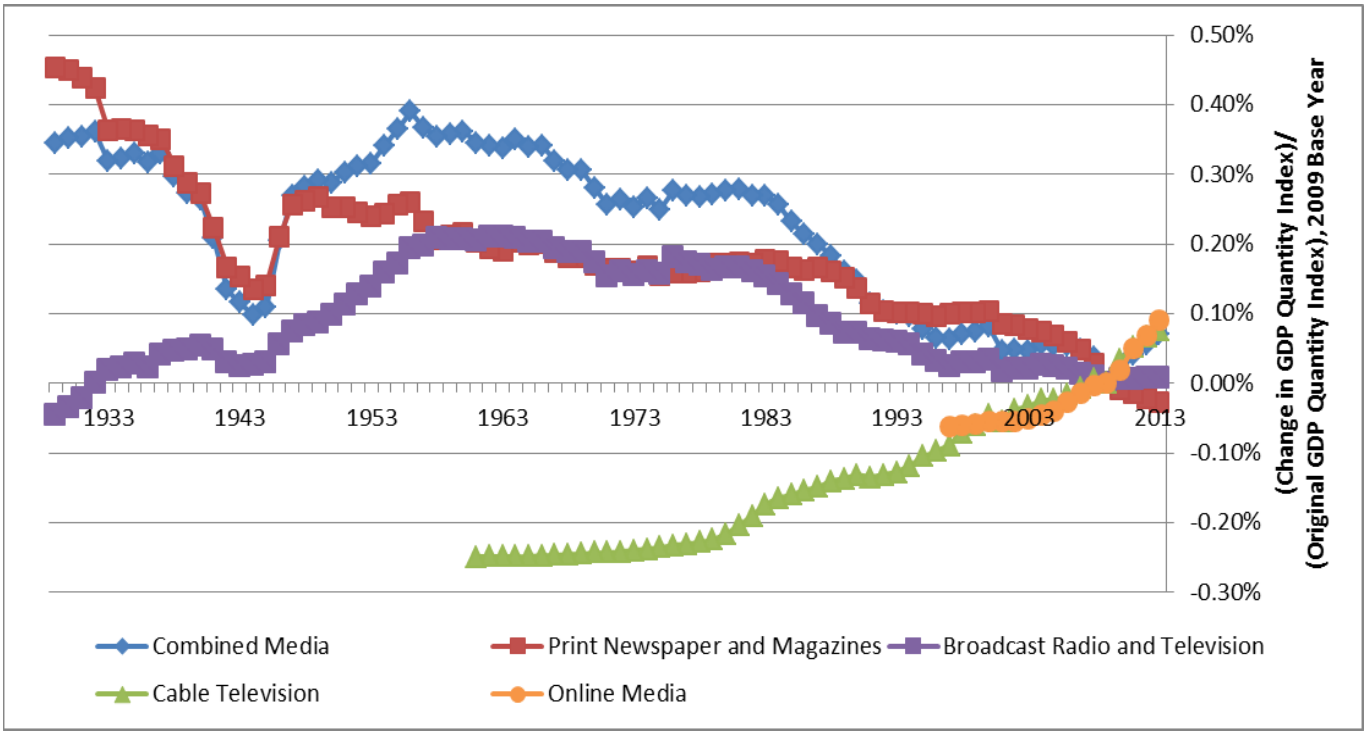

Figure 14: Quantity Indexes for Advertising Viewership

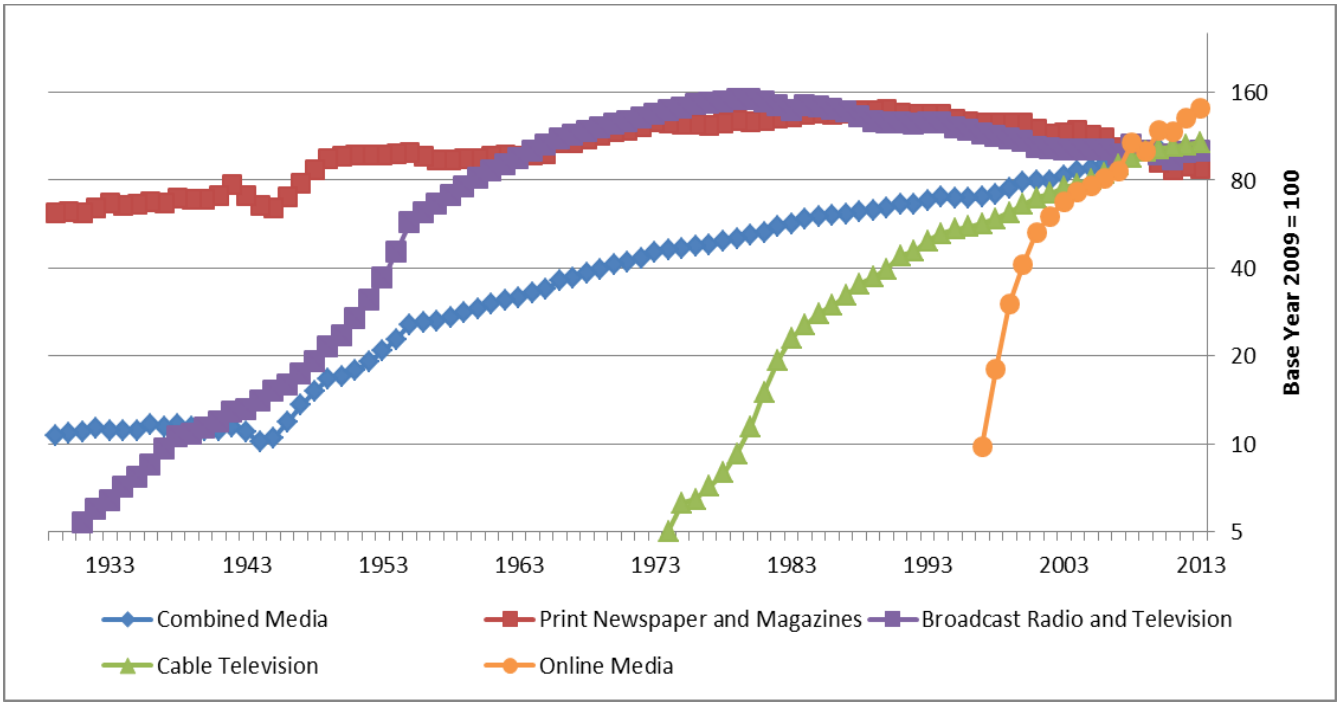

Figure 15: Change in Business Sector Total Factor Productivity from Online Media

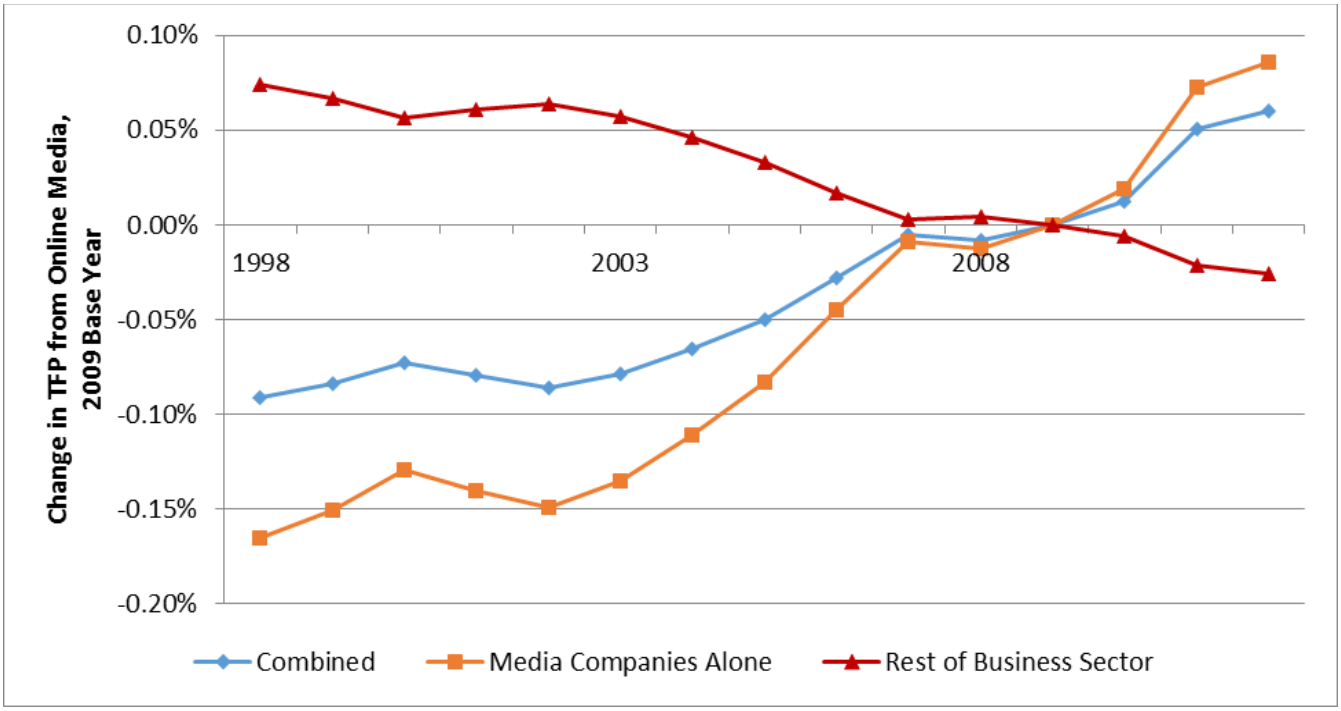

Figure 16: Change in Business Sector Total Factor Productivity from Quality-Adjusted Online Media, an Upper Bound Based on Bytes of Data

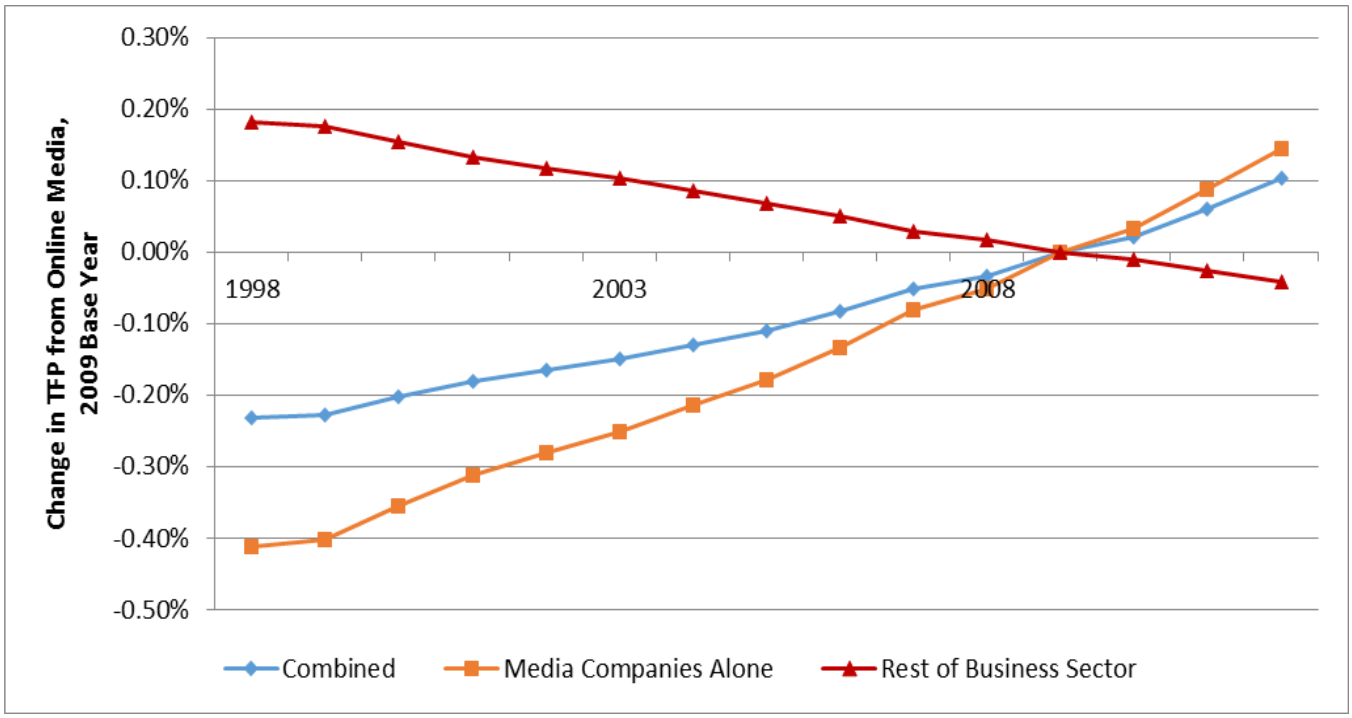

Figure 17: Change in Business Sector Total Factor Productivity from Print Media

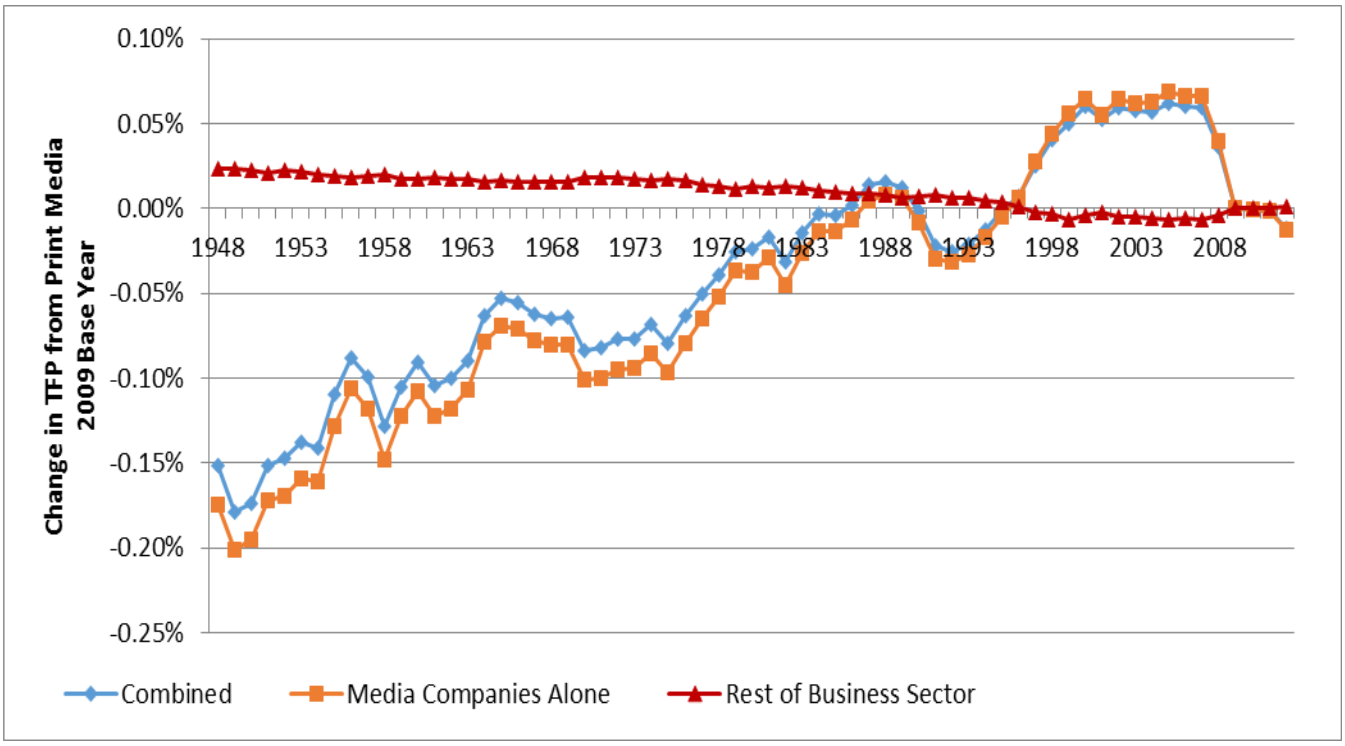

Figure 18: Change in Business Sector Total Factor Productivity from Broadcast Media

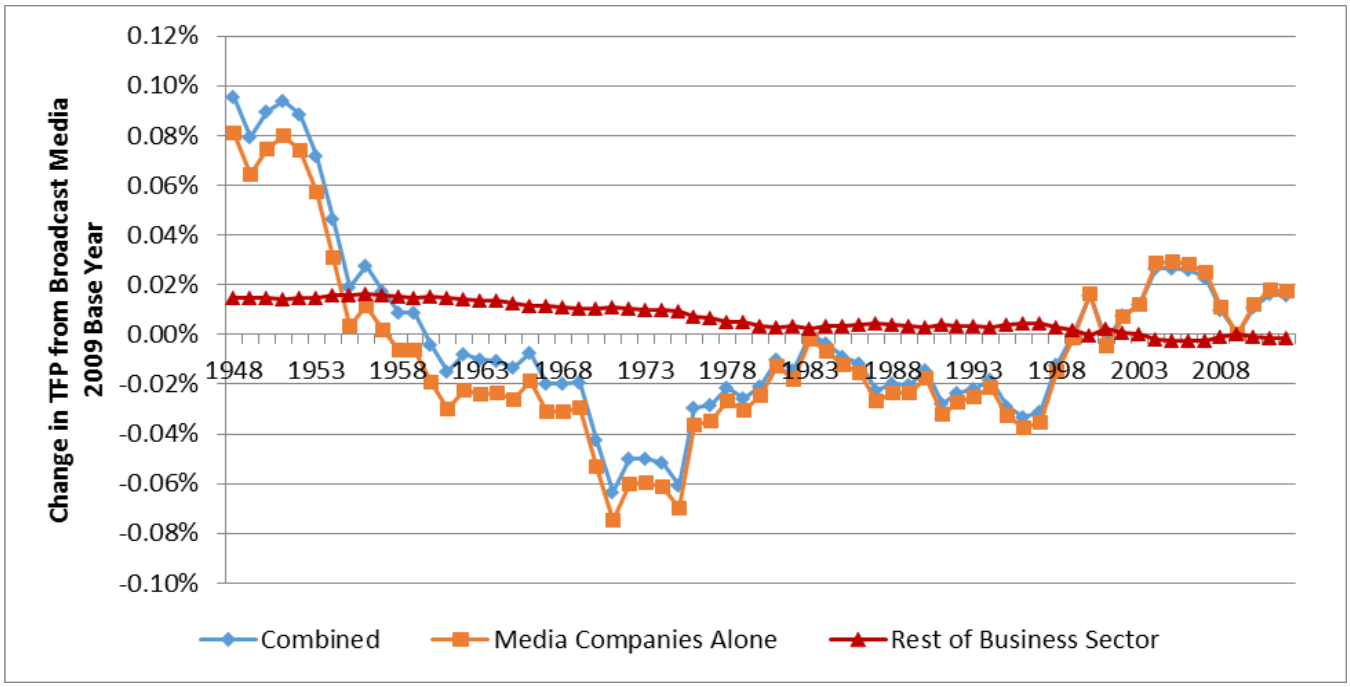

Figure 19: Change in Business Sector Total Factor Productivity from Cable Television

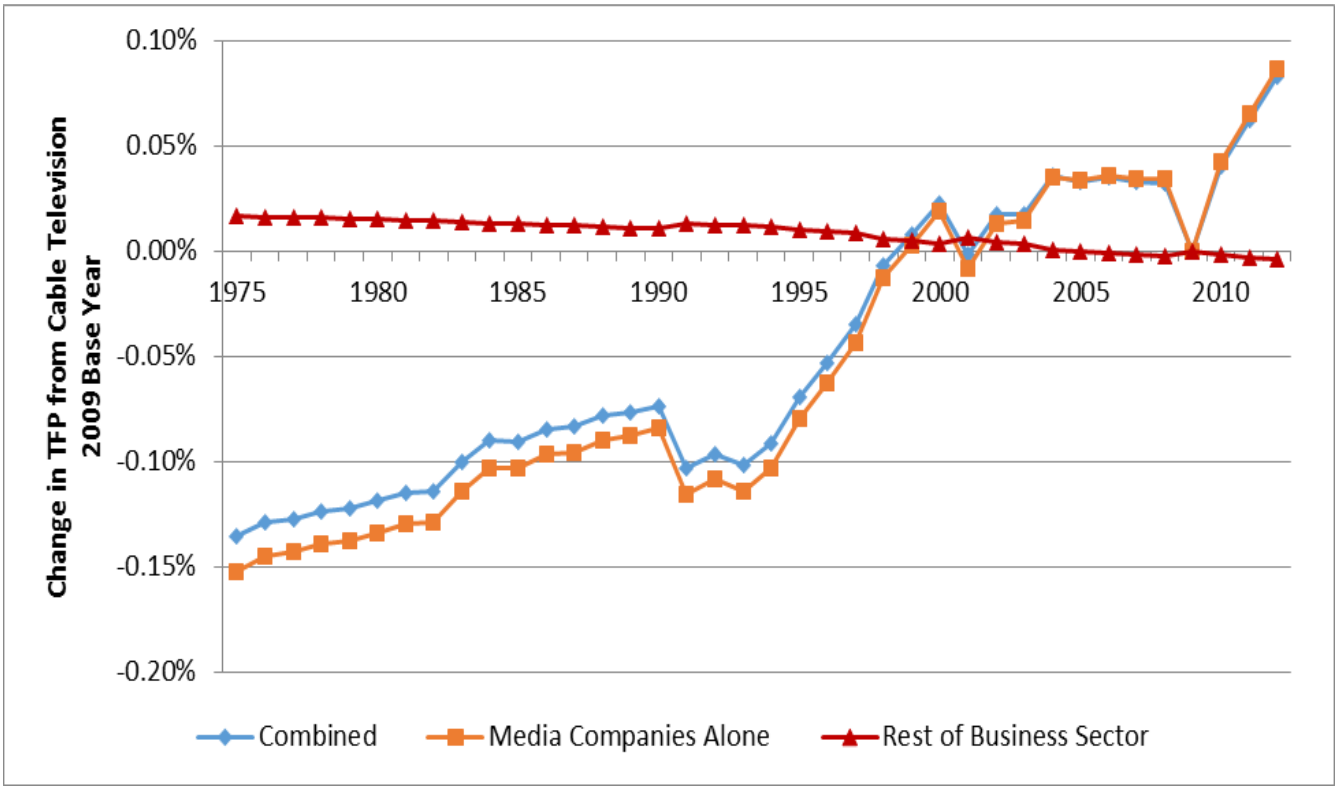

Figure 20: Change in Business Sector Total Factor Productivity from Nonmedia Internet Startups Supported by Venture Capital

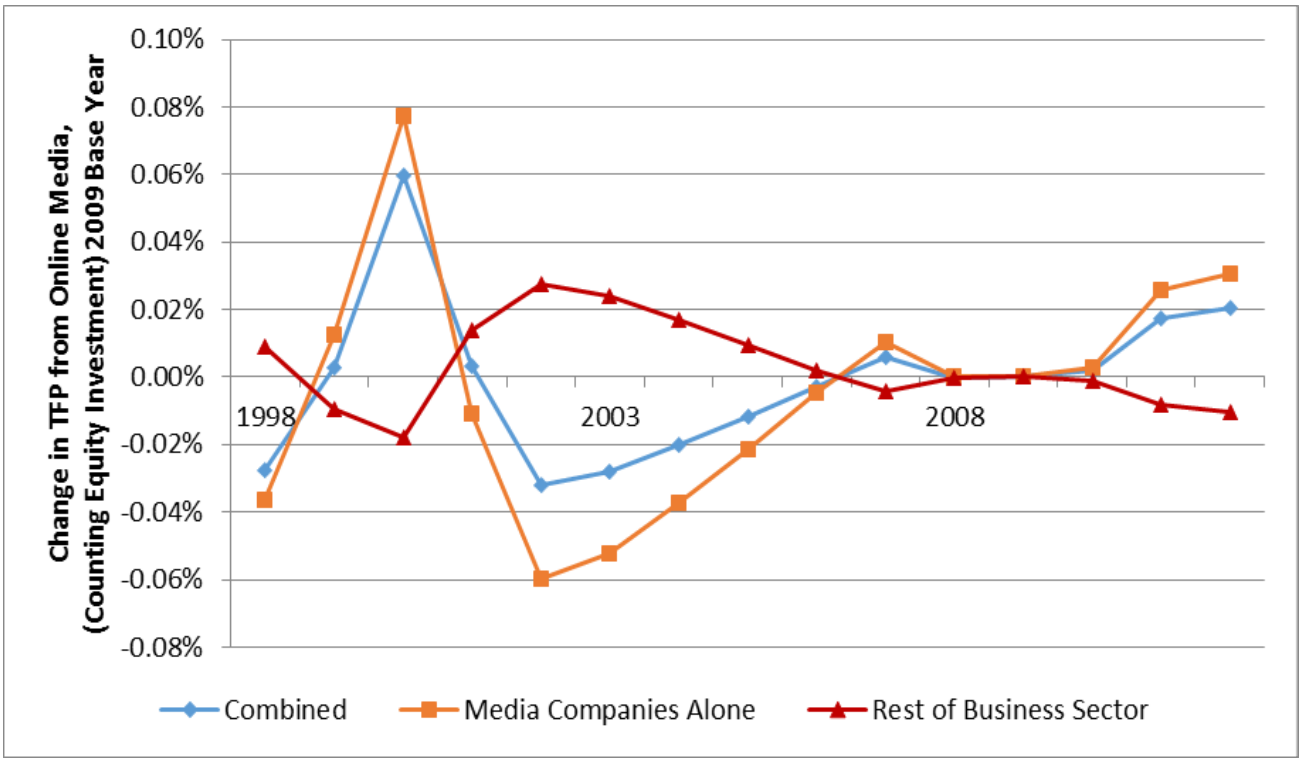

Table 1: New Funding of Internet Firms in Private Placements, U.S.

Year	Total Internet Private Placements, in millions	Year	Total Internet Private Placements, in millions
1998	$5,484	2007	$10,112
1999	$21,370	2008	$11,161
2000	$44,629	2009	$6,714
2001	$18,536	2010	$9,285
2002	$5,903	2011	$18,617
2003	$5,199	2012	$11,954
2004	$6,924	2013	$14,890
2005	$6,404	2014	$26,082
2006	$7,470	2015	$34,448

Source: S&P Global Market Intelligence

Appendix A: A Primer on the Experimental Accounting for "Free" Media

The basic premise of the economic accounting framework experimented with in this paper is that values for "free" media can be imputed in the input-output tables based on the advertising revenue that funds the "free" media. Conceptually, the idea of imputing components of current production that are not paid out of pocket is not new to GDP accountants. The largest imputed estimate in the national income and product accounts is owner-occupied housing services. For this component of GDP, there is no observed economic transaction between the owner of the dwelling and the owner-occupiers who consume the housing services. In this case, the rental equivalence method is used to impute the consumption of owner-occupied housing services and the corresponding income used to pay for the current housing services.[27]

The purpose of this Appendix is to provide details and discussion of the experimental accounting framework for free media and how it relates to the current treatment in the BEA's accounts. We demonstrate our experimental approach to measuring advertising-supported media by presenting a series of input-output tables that include the pertinent transactions. An advantage of viewing this through the input-output accounts is that these accounts form the foundation both for measuring GDP by industry and for measuring productivity at the industry level.

We begin with a stylized example with four sectors: (1) a sector (M) that produces media content (e.g., apps or books); (2) a sector that produces advertising, broadcasting, and publishing (APB); (3) an everything else (EE) sector; and (4) a household viewership (HV) sector. GDP is measured in two equivalent ways: (1) the sales to final demand (labeled C for consumption) and (2) the sum of value added generated by industry. Value added is composed of payments to factor services and taxes but can be thought of as payments to labor services in this example.

We start with the case of direct sales of media to final demand, compare this with the case of advertising-supported media under our current methodology, and then proceed to advertising-supported media under our experimental methodology. In all of our initial examples with advertising-supported media, the full value of the media is supported by advertisements, so

[27] Other examples include food furnished to employees and financial services indirectly measured (FISM). See the "Concepts and Methods of the U.S. National Income and Product Accounts" at http://www.bea.gov/national/pdf/NIPAhandbookch1-4.pdf.

that the viewer pays zero for the content. Partial advertising-supported media can be treated within the same framework, but the "free" media highlights the conceptual issues involved.

Direct Sales of Media

Table A1 depicts the input-output table for this stylized economy with direct sales of the media to final demand. Nominal GDP is $1,000, consisting of $800 of industry EE sales to final demand and $200 sales of media directly to final demand. Total final sales equal $1,000, the value added generated by the four sectors. In this economy, advertising is required to sell industry EE's output (industry EE purchases $250 worth of advertising services; think of this as direct mailings), and industry EE supplies $200 worth of product used in producing the advertising. In this example, the $200 of output of the media company M is sold directly to final demand. We imagine that this media comprises $100 of print media, such as short stories, and $100 of digital media, such as video games or apps. The HV sector has no role in this economy.

Table A1

	EE	APB	M	HV	C	Commodity Output
EE		200			800	1,000
APB	250					250
M					200	200
HV						0
VA	750	50	200			
Gross Output	1,000	250	200			

Current Treatment of Advertising-Supported Media

To produce an input-output table with advertising-supported media, we impose the following assumptions. First, actual consumption of the output of industry EE is unchanged from the case of direct sales. Second, real consumption and the price of apps are unchanged from the case of

direct sales. Third, by substituting the direct mailing with the media ad campaign, industry EE is able to save on labor dollar for dollar.[28]

Table A2 lays out an example of an economy with advertising-supported media and demonstrates some of the measurement drawbacks of the current approach to accounting for media's role in the economy.[29] In this example, we imagine print media are used to distribute advertising, but the two are basically equivalent in this stylized model. Because the consumer values print media at $100, the APB industry must pay the media company at least $100 for the media company to be willing to make the content free to consumers. We assume that the APB industry pays exactly $100. In this economy, industry EE switches between direct marketing and advertising bundled with the print media. For this privilege, industry EE pays APB $350, reflecting the value of the media content and the other ad-related services. The HV sector has no explicit role in this representation even though the APB sector is implicitly serving as an intermediary in delivering ad viewership to sector EE.

Table A2

	EE	APB	M	HV	C	Commodity Output
EE		200			800	1,000
APB	350					350
M		100			100	200
HV						
VA	650	50	200			
Gross Output	1,000	350	200			

[28] This precise assumption is made for modeling convenience. It ensures that GDP prices remain fixed. This may seem like a strong assumption, and it is, but it is relatively innocuous because the pertinent comparison is between the current treatment of advertising-supported media and our proposed treatment with the barter transaction. When comparing these two approaches, we need not make this assumption. We impose this here to make a broad comparison between how the input-output accounts would look with direct sales of media to make the point that the value of the media to the consumer must be bid away. We do not make use of any evidence to tell us how industries adjust with the introduction of advertising-supported media. We could have alternatively chosen to allow the value of the output of industry EE to increase, for example.

[29] We do not consider the underlying reason for the advertising-supported approach to selling media or the role of media in selling industry output, but our approach does allow for this media to be used as a productive input.

It is worthwhile to compare the aggregate economy measured economy in Table A1 with Table A2 even though this comparison embeds the assumptions imposed above. Imposing fixed prices allows for an easy comparison of aggregate nominal and real GDP. By assumption, the advertising-supported media does not increase the final sales of industry EE; thus, consumption of industry EE's output is unchanged from the example of direct sales. Similarly, the consumption of digital media and its price is the same. It is obvious from Table A2 that real measured GDP is lower than the economy measured in Table A1 because the same quantity of industry EE output is consumed, but only the digital media are measured in final consumption. Under this set of assumptions, the consumer is indifferent between the economy in Tables A1 and A2 (the same level of real consumption), and real production measured from final demand is the same, but measured GDP is lower. This is the crux of the measurement issue.

We note that this representation highlights the similarity between print and digital media. In this case, if the digital media was sold as an advertising device instead of the print media, Table A2 would look exactly the same.

Media Consumption as a Barter Transaction

Our experimental treatment of advertising-supported media recognizes the barter transaction that is implicit in the previous example of advertising-supported media.[30] The role of our imputed barter transaction is highlighted in Table A3. One way to think about the exchange is that the consumer was spending $100 for the print media (the direct sales case), but the current accounting does not capture this. Thus, we impute $100 to consumption of the media, which in this case is provided by the APB industry to final consumers. How does the consumer fund this consumption? This $100 of consumption is funded by an implicit payment from the APB industry, which in exchange for this payment gets exposure to the HV sector (people watching their ads). Thus, the APB sector generates advertising-supported media (to be viewed by the HV sector) in addition to primary ad services (which are purchased by the EE sector). Finally, the HV sector produces ad viewership output. Note that the digital media still are sold directly to consumers in this example.

[30] Note that there are many barter transactions in the economy, but we focus only on the transaction among the ad viewers, advertisers, and media producers. It is this channel that delivers the media of interest in this paper.

Table A3

	EE	APB	M	HV	C	Commodity Output
EE		200			800	1,000
APB	350				100	450
M		100			100	200
HV		100				100
VA	650	50	200	100		
Gross Primary Output	1,000	350	200			
Imputed Output of Ad-Supported Media		100				
Ad HV Output				100		

A complementary interpretation of the barter transaction in Table A3 is that the APB industry needs to deliver advertising viewership to the EE industry. To deliver this ad HV, the APB industry must compensate the HV sector. In this framework, the APB industry compensates the HV sector exactly the amount that the viewer is willing to pay for the media content.

At this point, we highlight that in our application, we do not observe the amount that the consumer is willing to pay for the media if it was sold directly. To estimate these values, we use observed advertising revenue.[31] That is, we use observations on the output of the advertising industry (the $350 in Table A3) to estimate the value of content to consumers and use this estimate as the value of the barter transaction. Note that, as Table A3 shows, this value includes the value of the media. This is discussed later in more detail. The key point from Tables A1–A3 is that our experimental methodology imputes a barter transaction valued at our estimate of the consumption value of the media.

It is instructive to compare the measurement framework with the imputed barter transaction with the current treatment. First, value added across the private industries is the same in the two treatments. The implication of this is that the additional imputed consumption is balanced by the additional value added produced by the HV sector. Second, the level of real value added is higher than in the current treatment. One interpretation of this is that compared

[31] Advertising revenue in any given period may not equal advertising spending, but this is a common problem in constructing balanced input-output accounts. Because of data constraints, we rely on ad revenue.

with the current treatment, the value added of the HV sector allows the consumer a higher level of consumption compared with the treatment without the barter transaction.

It is immediately apparent that conditional on the assumptions listed, our experimental approach produces the same nominal and real GDP as would have occurred under the direct sales model. This is the fundamental justification for our experimental approach. Conceptually, we believe that advertising-supported media are a very close substitute for directly purchased media, so the two media types should be handled similarly in the national income and product accounts. Under the current GDP formula, advertising-supported media are entirely excluded from final output and contribute to GDP only indirectly. In contrast, our experimental approach includes both directly purchased media and advertising-supported media in final output. Furthermore, we argue that this is a useful feature because a significant portion of media consumed is through advertising-supported media.

Viewership Sector as Part of the Broader Household Sector

In these stylized examples and in the analysis in the main text, we have introduced a viewership sector that is beyond the scope of BEA's current set of economic accounts. To minimize the deviation of our analysis from BEA's official accounts, we do not consider the production process for this viewership. Presumably, ad viewership requires other inputs such as a television, a mobile phone, or a kitchen table to read the magazine. Measuring the output and inputs of this process is entangled with measuring overall household production and productivity in the household sector. We intentionally avoid this because of the plethora of issues involved in measuring household production. Our estimates of TFP at the industry level, however, are separable from measuring the inputs to household ad viewership; thus, our focus is on the role of advertising-supported media in industry TFP measurement.

Media Use by Business

Our examples in Tables A1 to A3 assume that media content is valuable only to consumers. Tables A4 to A6 revisit the same conceptual issues when the final content is valuable to business. In Table A4, the media produced by industry M is purchased directly by industry EE.

To clarify, we imagine a situation in which the media are directly relevant to the production process of industry EE (e.g., the *Wall Street Journal* for a financial industry or Waze apps for a moving company). This is distinct from the case earlier in which the industry only valued the media as a conduit to reach ad viewers. Just as with the earlier consumer entertainment example, businesses provide ad viewership in return for media content.

Table A4

	EE	APB	M	HV	C	Commodity Output
EE		200			1,000	1,200
APB	250					250
M	200					200
HV						0
VA	750	50	200			
Gross Output	1,200	250	200			

In this example of economy with direct sales of media to business, nominal GDP is $1,000. Similar to the case earlier, industry EE requires $250 worth of advertising to sell its output, and the media producer makes $200 worth of media. Unlike the case earlier, these media are purchased as an intermediate input into the production of EE.

Table A5 provides a demonstration of what happens to the input-output account with advertising-supported free media. Again, we imagine that $100 of the media is provided by the APB media, and as noted earlier, whether it is the digital or print media, the input-output accounting is the same. In this case, the industry EE values the media at $100, so the APB industry must pay the media producer $100 to bid this away. Given the value of the media content embedded in the advertising services produced by the APB industry, industry EE pays the media industry $350 for the ad services, including the media content. Under this model, industry EE is indifferent between the direct sales model and the advertising-supported media because it receives the same quantity of intermediate inputs for the same prices as under the direct sales. Because media are used as an intermediate input, aggregate GDP is unchanged with the advertising-supported media model compared with the case in which the media are purchased directly as an intermediate input.

Table A5

	EE	APB	M	HV	C	Commodity Output
EE		200			1,000	1,200
APB	350					350
M	100	100				200
HV						
VA	750	50	200			
Gross Output	1,200	350	200			

Similar to the case with media consumed by households, the ad-supported media model leaves out the implicit transaction between the viewer and producer of the ads. Table A6 highlights these barter transactions. In this case, industry EE produces ad viewership in addition to its primary output. Similar to the case of consumers, the APB industries implicitly compensates the viewers $100, which funds the business consumption of the advertising-supported media in sector EE. The APB industry has $100 of imputed output of advertising-supported media so that a total of $450 of input from the APB industry is purchased by industry EE. The intuition for this is that because the industry APB paid $100 to obtain the rights to use the media content, this must be worth at least $100 to the APB industry. This value accounts for an implicit payment that must be made to the viewers of the ads. The account in Table A6 makes this payment explicit and produces an internally consistent accounting for ad-supported media that reflects both the recorded and implicit payments for the media as an output and an input.[32]

Table A6

	EE	APB	M	HV	C	Commodity Output
EE		200			1,000	1,200
APB	450					450
M	100	100				200
HV		100				100
VA	750	50	200			

[32] Note that the HV sector is uninvolved in this example. The payment for ad viewership goes to the business sector, which produces the ad viewership as a secondary product. Thus, there is no entry in the value added of the HV column.

Gross Primary Output	1,200	350	200
Imputed Output of Advertising-Supported Media		100	
Ad Viewership Output	100		

Industry and Aggregate Productivity Measurement with Our Experimental Approach

Given our reconstructed input-output table, measures of industry growth and productivity that reflect our experimental approach are relatively straightforward. Productivity measures require prices and quantities for the outputs and inputs of each sector. Productivity growth is defined as the growth rate of the ratio of the quantity index of output to the quantity index of input.

On the output side of each industry's production account, there are potentially eight new outputs discussed in the main text: (1) advertising-supported print media, (2) advertising-supported broadcast radio and television, (3) advertising-supported cable television, (4) advertising-supported online media, (5) print media viewership, (6) broadcast media viewership, (7) cable television viewership, and (8) online media viewership. We construct new measures of the price and quantity of industry output as the Tornqvist index of the original industry output with these eight new outputs. Data for the prices and quantities for each of these are described in the body of the paper and in Appendix B.

At first glance, it seems surprising to create so many new outputs for each industry. In fact, having a single industry produce multiple outputs is not uncommon in productivity measures. The official BEA–BLS integrated industry-level accounts use this approach, and industries are classified by their primary production. For cases in which a single industry produces multiple outputs in the official BEA accounts, industry output growth is a chained index over multiple outputs.

On the input side of the production account, each industry has these same eight potentially new inputs. We construct new measures of the price and quantity of industry input as the Tornqvist index of the original industry input with these eight new inputs. Data for the prices and quantities for each of these are described in the data appendix.

We reiterate that, by construction, the nominal value of new outputs equals the nominal value of new inputs by industry. However, the price of each of these is different on the output side and the input side of the account; thus, the barter transaction has implications for measured industry TFP. The government and viewership sectors complicate aggregation across industries to economywide totals. Thus, we focus on the measured productivity impact on the private economy.

Free Media in the 2007 Input-Output Accounts

Table A7 demonstrates how the barter transactions impact the 2007 BEA input-output table (modified to include a viewership sector) for 15 broad sectors that encompass the U.S. GDP. We reiterate that the starting point for these values is data on advertising revenue. We do not have data on the spending on the media content directly. In the main text and in Appendix B, we describe how we estimate the value of each form of media embedded in advertising revenue.

Table A7a shows the production and use of ad-supported media content; that is, our estimate of the value of media content embedded in advertising revenue. In 2007, print, broadcast, and online media combined for $98 billion in media content. We estimate that $79 billion accrued to the viewership sector. The remainder (about 20%) of the value was used by U.S. businesses and government. To be clear, by construction, the sum of the value added generated by the viewership sector plus the intermediate use of the media equals the estimated value of advertising-supported media. Table A7b highlights that the value ad-supported media content equals the value of viewership output across the economy; that is, the total value of output from media viewership across all sectors equals the value of advertising-supported media content. The table makes it clear that within industries, the value of media being used equals the secondary production value of media viewership.

Table A7a

Commodities/Industries	11	21	22	23	31G	42	44RT	48TW	51	FIRE	PROF	6	7	81	G	HV
11: Agriculture, forestry, fishing, and hunting	71.1	0.1	0.0	1.7	202.9	1.5	1.6	0.1	0.0	0.0	1.1	0.5	5.7	0.1	1.8	
21: Mining	2.1	54.7	74.7	12.3	422.2	0.1	0.2	4.6	0.3	4.8	1.3	0.6	1.3	0.5	18.6	
22: Utilities	5.2	4.9	5.2	3.3	80.2	6.9	16.1	6.4	3.8	80.7	11.5	19.8	15.3	4.3	26.5	
23: Construction	2.3	7.2	7.4	0.2	13.9	1.5	2.9	4.3	2.2	111.5	2.1	2.2	2.5	3.0	57.0	
31G: Manufacturing	70.6	37.2	31.5	364.0	1897	40.7	44.7	162.0	82.3	82.5	131.1	149.5	119	47.6	337.1	
42: Wholesale trade	21.6	5.7	5.2	51.0	257.3	28.0	17.0	22.0	12.9	11.6	17.8	31.7	16.7	7.0	37.0	
44RT: Retail trade	0.2	0.2	0.5	76.8	11.4	0.6	5.0	4.2	0.3	7.4	2.0	1.0	6.2	4.1	0.5	
48TW: Transportation and warehousing	10.3	9.0	23.1	21.4	123.2	46.4	54.7	93.8	16.6	28.1	35.2	16.2	11.0	4.2	48.8	
51: Information	0.4	0.9	2.1	3.8	22.8	12.2	13.3	5.4	164.4	65.0	56.2	22.6	9.2	8.1	72.3	
FIRE: Finance, insurance, real estate, rental, and leasing	15.5	13.8	19.4	29.2	92.6	92.6	140.9	76.8	61.3	928.5	222.6	231.9	83.5	80.2	115.6	
PROF: Professional and business services	4.2	22.7	28.5	44.0	339.6	146.0	124.0	51.0	124.2	420.3	419.0	166.2	106	31.9	254.2	
6: Educ. services, health care, and social assist.	0.2	0.0	0.1	0.0	0.1	0.5	2.2	0.1	0.2	0.1	0.5	20.4	1.3	1.5	13.8	
7: Arts, entertain., rec., accomm., and food service	0.4	0.6	3.6	2.1	15.5	5.1	3.7	3.2	26.4	45.7	45.6	19.3	22.0	2.9	26.5	
81: Other services, except government	0.8	0.5	1.0	4.4	16.1	15.0	10.5	4.8	7.7	30.3	27.2	22.5	10.3	6.1	23.4	
G: Government	0.1	0.0	0.8	0.0	5.2	11.5	6.4	18.7	3.7	9.2	8.7	5.7	6.1	1.8	8.1	
Original Intermediate	205	157	203	614.4	3500	409	443	457	506	1826	982.0	710	416	203	1041	
Advertising-supported print media	0.014	0.023	0.023	0.056	0.251	0.065	0.043	0.040	0.076	2.427	0.124	0.096	0.046	0.026	0.053	
Advertising-supported broadcast media	0.002	0.012	0.013	0.030	0.136	0.035	0.023	0.022	0.041	6.382	0.067	0.052	0.025	0.014	0.029	
Advertising-supported cable media	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Advertising-supported online media	0.101	0.163	0.168	0.405	1.803	0.468	0.306	0.289	0.543	2.142	0.891	0.690	0.328	0.186	0.380	
Print media viewership	0.004	0.007	0.002	0.002	0.042	0.002	0.002	0.018	22.024	0.013	0.013	0.009	0.009	0.002	0.004	
Broadcast media viewership	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15.511	0.000	0.000	0.000	0.000	0.000	0.000	
Cable media viewership	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	42.937	0.000	0.000	0.000	0.000	0.000	0.000	
Online media viewership	0.004	0.005	0.002	0.002	0.034	0.002	0.002	0.014	17.830	0.011	0.011	0.007	0.007	0.002	0.007	
Total Intermediate	205.1	157.6	203.4	614.9	3502.3	409.2	443.5	457.7	605.2	1836.6	983.1	710.9	416.3	203.5	1041.9	.
V001: Compensation of employees	41.5	62.7	63.1	439.8	944.4	429.2	506.1	255.8	260.4	730.0	1183.3	895.8	324.7	231.1	1541.0	.
V002: Taxes on production and imports, less subsidies	-2.5	33.6	54.6	7.9	60.2	175.3	184.3	24.6	43.1	247.9	49.8	32.0	70.5	17.3	-18.7	.
V003: Gross operating surplus	103.0	217.7	117.4	267.3	849.7	256.3	187.2	129.1	398.8	1899.2	424.1	136.8	137.0	82.1	382.9	.
Total Value Added	142.0	314.0	235.1	715.0	1854.3	860.8	877.6	409.6	702.4	2877.1	1657.2	1064.6	532.1	330.5	1905.2	79

Table A7b

Commodities/Industries	11	21	22	23	31G	42	44RT	48TW	51	FIRE	PROF	6	7	81	G	HV
Original Industry Output	346.9	471.4	438.2	1329.4	5354.4	1269.5	1320.7	866.9	1208.6	4702.8	2639.2	1774.7	948.0	533.8	2946.7	.
Media-Related Output																
Advertising-supported print media	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Advertising-supported broadcast media	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Advertising-supported cable media	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Advertising-supported online media	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0
Print media viewership	0.014	0.023	0.023	0.056	0.251	0.065	0.043	0.040	0.076	2.427	0.124	0.096	0.046	0.026	0.053	19
Broadcast media viewership	0.002	0.003	0.003	0.008	0.036	0.009	0.006	0.006	0.011	1.694	0.018	0.014	0.007	0.004	0.008	14
Cable media viewership	0.006	0.009	0.009	0.022	0.100	0.026	0.017	0.016	0.030	4.688	0.049	0.038	0.018	0.010	0.021	38
Online media viewership	0.101	0.163	0.168	0.405	1.803	0.468	0.306	0.289	0.543	2.142	0.891	0.690	0.328	0.186	0.380	9
Total Industry Output	347.1	471.6	438.4	1329.9	5356.6	1270.0	1321.1	867.3	1307.5	4713.7	2640.3	1775.5	948.4	534.1	2947.1	98

Appendix B: Detail Discussion of Data Sets Used

Production of Media by Industry: 1929–2014

Before the Internet, the mapping between media categories and industries was straightforward: Publishers (NAICS 511) produced print media, and networks (NAICS 5151 and 5152) produced cable television and broadcast radio and television media. The Internet makes the situation more complicated. The majority of online media are produced by Internet-only publishers such as Google or Yahoo! (NAICS 519). However, print media publishers also produce online content such as digital news stories or blogs. Conversely, Internet publishers such as YouTube sometimes host videos for a variety of professional content producers.[33]

Unfortunately, the Economic Census does not report online advertising revenue for print publishers or video revenue for Internet publishers. The only data tracked are total advertising revenues for each industry.[34] We use a variety of data sets to split industry advertising revenue by media category. According to the Newspaper Association of America, digital advertising accounted for 15% of total advertising in 2012, 7% in 2007, and 2% in 2002.[35] We were not able to find similar data on magazines, but the Service Annual Survey (SAS) does track the overall share of revenue earned online. This total includes both digital advertising revenue and digital subscription revenue. We assume that both revenue sources have the same digital share.[36] Based on that assumption, we estimate that digital advertising accounted for 18% of magazine revenue in 2012, 9% in 2007, and 4% in 2002. Finally, we use annual reports published by the Internet Advertising Bureau and other sources to track online radio and television advertising. Based on

[33] Many of the content producers are not yet profitable. Nevertheless, we classify them as professional because they are aspiring to earn money from their channels eventually. In addition, YouTube hosts many pure amateurs.

[34] The 2002 Economic Census does track online advertising revenue separately. But the numbers are very small and hard to extrapolate forward.

[35] The Newspaper Association of America only reports digital advertising back to 2003. Between 2003 and 2004, the digital share for newspapers grew 21%. We assume the same growth rate between 2002 and 2003.

[36]The Service Annual Survey data starts in 2005. We assume that the digital share grew 27% annually before 2005. For newspapers, the Service Annual Survey reports total online revenue smaller than the Newspaper Association of America reports for online advertising alone. We are not sure for the reason behind this difference.

these data sets, we estimate that videos accounted for 10% of online advertising in 2012 and 1% in 2007. [37]

Before 2002, we could not find any data on online advertising revenue by industry. We assume that the industry split is fixed at 79% Internet-only publishers, 20% print publishers, and 1% networks. Our TFP numbers do not currently extend after 2012, so it is not yet necessary to calculate the industry split after the 2012 Economic Census. Online advertising revenue is becoming a very large fraction of newspaper and magazine advertising revenue. We hope that the census will eventually recognize the importance of online advertising and track it separately.

Nominal Advertising Revenue by Media: 1929–2014

Our primary data set is the 2007 Economic Census. That census reports advertising revenue for newspaper publishers (NAICS 51111), magazine publishers (NAICS 51112), radio broadcasters (NAICS 51511), television broadcasters (NAICS 51512), cable networks (NAICS 5152), and Internet publishers (NAICS 516 in 2002 and 51913 in 2007 and 2012). At the time this draft was written, the final 2012 Economic Census was not yet available. Therefore, we benchmarked all of our numbers to the 2007 Economic Census. Results are very similar if we use the preliminary 2012 Economic Census for benchmarking. As we discussed earlier, the Economic Census tracks total advertising revenue by industry but does not reliably split advertising revenue by media category. We used the media splits by industry calculated earlier to estimate advertising revenue by media category.

For print newspapers, the Newspaper Association of America provides the time series data from 1950 until 2013; these data are available on its website for free.[38] Before 1950, we use estimates from the CS Ad Expenditure Dataset; these data are also available online for free.[39] Results are similar if we use data from the SAS or the Economic Census, but these sources require more work to create a consistent time series.

[37] Advertising-supported online video always existed, but it was very small before YouTube was bought by Google in November 2006. The Internet Advertising Bureau's data start in 2007, when the digital video share was 1.34% of total online advertising.

[38] "Newspaper Media Revenue 2013: Dollars Grow in Several Categories," Newspaper Association of America, www.naa.org/Trends-and-Numbers/Newspaper-Revenue.aspx.

[39] Douglas Galbi, "U.S. Advertising Expenditure Data," purple motes, September 14, 2008, www.purplemotes.net/2008/09/14/us-advertising-expenditure-data.

For print magazines, the SAS provides our total magazine advertising from 2005 until 2013. The Economic Census provides total magazine advertising from 1947 to 2007. Finally, we use the CS Ad Expenditure Dataset before 1947 and as an interpolator between Economic Census years. None of these data sets splits online advertising revenue from print advertising revenue. We use the online share estimates developed earlier to estimate print revenue alone.

For radio, the SAS provides our time series from 2007 onward. Before 2007, we use the CS Ad Expenditure Dataset. Neither of these data sets split online advertising from broadcast advertising. We subtract the online advertising estimates developed earlier to get offline revenue alone.

For television, the SAS provides our time series from 2011 onward. Before 2011, we use data collected earlier for a previous paper on long-lived television programs (Soloveichik 2013b). Unlike print media and radio, advertising-supported television shows up in two NAICS codes: 5151 for broadcast television and 5152 for cable television. We add the two categories of television advertising to get total advertising. Similar to the other media categories, we subtract the online advertising estimates developed earlier to get offline revenue alone.

Forrester Data on Media Time Use: 1929–2014

Our primary data on time use are provided by Forrester, a survey company. Forrester has been surveying Americans about their media time use since 1999. Our paper uses data from Forrester's questions on weekly time use for "reading newspapers (not online)," "reading magazines (not online)," "listening to the radio (not online)," "using the Internet for personal purposes," and "using the Internet for work purposes." Similar to most firms conducting surveys, Forrester relies on self-reported data and does not attempt to check the answers against objective source data such as Internet cookies. We do not know either the size or direction of the possible misreporting. For now, we use Forrester's data on newspaper readership, magazine readership, radio listenership, and total Internet usage without adjustment.

Forrester's survey does not ask respondents for the exact amount of media usage. Instead, they are asked to check boxes giving the time use category. The lowest category is "none," and the highest category is "30 or more hours." In some of its published reports, Forrester creates a continuous variable by replacing each box with the midpoint of the range. In particular, the mapping is none = 0, less than 1 hour = 0.5, 1 to 4 hours = 2.5, 5 to 9 hours = 7, 10 to 14 hours =

12, 15 to 19 hours = 17, 20 to 24 hours = 22, 25 to 29 hours = 27, and 30 or more hours = 32. This average usage is held fixed over time. In this paper, we have used a statistical methodology described by von Hippel et al. (forthcoming) to estimate the mean for the top-coded bin, using a Pareto distribution for the top-coded bin (30 + hours per week) and the next-to-top-coded bin (27–29). For the nontop-coded bins, we used midpoints, as Forrester does. In future work, we plan to use a parametric methodology for estimating the mean using the generalized beta distribution to model the entire distribution of binned data. This has the advantage of not throwing away any information, but it leans much more heavily on distributional assumptions. Having two methods should enable us to have at least some notion of how sensitive our estimates are to the statistical methodology used. Our imputed numbers should not be attributed to Forrester.

Forrester's survey also does not ask respondents to split media usage between advertising-supported media and subscription media. This is most problematic for the Internet, where subscription media websites such as Netflix account for a large share of total time usage. In addition, many Internet users spend time on nonmedia websites such as online shopping, or mobile banking. For now, we assume that advertising-supported media time tracks overall media time.

Other Data on Media Time and Media Consumption: 1929–2014

We use Nielsen data to track television viewership back to its beginning. We did not buy Nielsen's full data for this purpose but rely on the summaries prepared by the nonprofit trade association TVB. All of the Nielsen data were taken from TVB's website (www.tvb.org), where it is available for free. Forrester also tracks television viewing time, and we could use its data from 2007 onward. However, the Forrester data are much noisier than the Nielsen data, so our annual TFP numbers are a little more volatile.

We use a variety of data sets to track radio listenership. From 2007 to 2014, we use Forrester's survey question on "radio listening (not online)."[40] From 1980 until 2007, we use Arbitron data. Similar to the Nielsen data, we did not buy Arbitron's full data set. Instead, we

[40] Forrester reports a very small decline in offline listening between 2007 and 2014. Over the same time period, Arbitron's data show a much larger decline. This decline may be associated with measurement changes rather than competition from online radio. See Kurt Hanson, "Radio's AQH Decline and the PPM," RAIN News, January 10, 2014, http://rainnews.com/radio-aqh-decline-ppm.

rely on a summary prepared by the Corporation for Public Broadcasting, which reports total radio listenership for each year from 1980 to 2010.[41] We also found Arbitron data for 1972 cited in the book *American Broadcasting* (Lichty and Topping 1975). We could not find any systematic ratings for radio before 1972. However, we found an article, "More Power" (*Sponsor Magazine* 1949), that reports radio listenership in 1949, 1946, and 1943. Before 1943, we could not find any usable data on listenership time. As a rough proxy, we use the percentage of households that owned radios and the percentage of cars equipped with radios.[42]

Neither the Nielsen TV viewership data nor the Arbitron radio listenership data split advertising from advertising-supported entertainment. For television, we use data from the Internet Movie Database (IMDb) website to split viewership between programs and advertising. IMDb does not directly report the amount of advertising viewership, but it does report the run times for individual episodes. Between 1960 and 2013, the time devoted to commercials grew from 15% of broadcast time to 28% of broadcast time. We could not find similar data for radios, but the book *Radio After the Golden Age: The Evolution of American Broadcasting Since 1960* (Cox 2013) suggests that radio commercial time grew at approximately the same rate as television advertising time. This increased advertising time lowers measured TFP growth. In Figure 14, we calculated that advertising-supported broadcasting raises TFP growth by 0.005% per year from 1960 to 2012. If the commercial time share had remained fixed, then advertising-supported broadcasting would have raised TFP 0.009% instead.

We use data from the Statistical Abstract of the United States to track Internet usage.[43] All of the tables in the Statistical Abstract explicitly focus on leisure Internet usage and do not include on-the-job Internet usage. Accordingly, we need to adjust the Statistical Abstract data for on-the-job Internet usage. We have not been able to find any data tracking on-the-job Internet time before 2007. As a proxy, we use data from the Current Population Survey (CPS) that track whether respondents have Internet *access* at work. During the 1990s, the Internet was more

[41] In particular, we use the series "6a–Mid 12+ Persons Using Radio AQH Rating." This series reports the percentage of people who are listening to the radio at any given time.

[42] For now, we give home radios and car radios an equal weight when calculating listenership. We multiply both proxies by population to get an estimate of total listenership.

[43] Taken from Table 1094 of the 2010 *Statistical Abstract*, Table 1089 of the 2009 *Statistical Abstract,* Table 1110 of the 2007 *Statistical Abstract*, Table 1119 of the 2004 *Statistical Abstract*, Table 1125 of the 2003 *Statistical Abstract*, and Table 1102 of the 2002 *Statistical Abstract*. All these tables explicitly focus on leisure Internet usage and do not include on-the-job Internet usage. We adjust for the on-the-job share to get total Internet usage.

common in the workplace, and workplace Internet tended to be faster. Based on that trend, we believe that on-the-job Internet accounted for a larger share of usage.

Newspapers and magazines are the hardest media category to track. From 2007 to 2014, we use Forrester's survey on time usage. From 1965 until 2007, we use readership data from Pew Research Center for the People & the Press surveys conducted periodically and reported in "In Changing News Landscape, Even Television is Vulnerable" (Kohut et al. 2012). Before the Pew survey data, we use the article "Radio Declares: 'Compare Me'" (*Sponsor Magazine* 1961)[44] to get a snapshot of readership in 1961. Between the years with data, we use newspaper and magazine circulation to interpolate annual readership. We also use newspaper and magazine circulation to extrapolate readership before 1961.[45]

Splitting "Business Information" and "Consumer Entertainment": 1929–2014

Forrester's reported split between "work Internet" and "personal Internet" usage is not equivalent to our split between "business information" and "consumer entertainment." Our paper is focused on measuring productivity by industry in the private business sector, so we consider business information to be Internet used on the job for job-related purposes. Consumer entertainment covers both leisure activities such as browsing YouTube and household production such as scheduling medical procedures or paying bills. In contrast, Forrester's respondents appear to have a broader definition of work Internet usage. Approximately two-thirds of full-time students report using the Internet for work, and many of these students report very high usage. These students are almost certainly reporting their homework and other study time as work Internet usage. In addition, retirees and other individuals not employed[46] also frequently report using the Internet for work. These individuals are probably reporting household production activities as

[44] This article gives an estimate for radio listenership. However, the estimate is much lower than Arbitron's numbers. We believe that this difference is caused by survey respondents underreporting background radio while driving or doing other activities. Forrester's survey shows the same underreporting relative to Arbitron.

[45] The Newspaper Association of America provides circulation back to 1940 (www.naa.org/Trends-and-Numbers/Circulation-Volume/Newspaper-Circulation-Volume.aspx). The Census of Manufactures also provides data on circulation for both newspapers and magazines back to the 1920s. In addition to these circulation data, the 1949 *Sponsor* article used earlier for radio also contains some data on print readership. However, that article is based only on two high education cities (Des Moines; Iowa; and Springfield, Massachusetts), which we thought were too unrepresentative to use for readership tracking.

[46] A few respondents report multiple employment categories. We drop those individuals.

work. We calculated the true business information share by replacing reported work Internet with zero for all individuals not employed.

Forrester does not ask respondents to split print media readership, television viewing, or radio listening between work and personal usage. In the absence of reliable time use data, we use a variety of proxies to split business information and consumer entertainment. For print media, we use genre data reported in the Economic Census and other sources. For example, we assume that scientific journals are used for work rather than leisure. Very few of the shows on broadcast radio or television are targeted toward business information. For now, we assume that on-the-job users account for only 1% of advertising.

Finally, we adjust for a conceptual difference between the national income and product accounts and everyday conversation. In the BEA's GDP statistics, owner-occupied housing is treated as if it were part of the business sector. Consistent with this treatment, free media products that help people buy, finance, or maintain their homes should be treated as intermediate inputs rather than final consumption. However, the Forrester survey respondents and the Economic Census almost certainly define home purchases as a personal activity rather than a work activity. We assume that the housing share of GDP is a proxy for the housing share of personal media usage.

Usage of Media by Industry: 1929–2014

Our primary data are the same Forrester survey data described earlier. In 2013 and 2014, Forrester asked respondents, "In which industry/field do you work?" Forrester provided only 30 codes for this question, and a few of codes do not represent industries.[47] We used our best judgment to match the Forrester codes with the 63 private sector industries tracked in the joint BLS–BEA production accounts. Reassuringly, reported time usage in the Forrester survey is highly correlated with reported Internet access in the CPS.[48]

[47] For example, one answer was "nonprofit," which could correspond to many industries. We do not match these codes to any of the NAICS codes. In addition, many of the Forrester codes are matched to multiple NAICS codes. Some individuals report multiple industry or field codes to Forrester. We drop all of these individuals from our sample.

[48] The relationship between Internet access and usage is not one to one. In the CPS data, Internet access ranged from 15% for industries such as agriculture to 70% for industries such as publishing. The Forrester data show a much

We were not able to find any data tracking usage of print media or broadcast media by industry. For now, we use Internet usage by industry as a proxy for these media categories. We were also unable to find any data on media usage by industry before 2013. For now, we use total industry output and total work Internet usage as extrapolators. For example, agriculture is assumed to use a very small share of print media output in 2013, but it accounted for a much larger share of business information in 1948. Our aggregate TFP numbers are robust to changing the industry allocation procedure, but TFP for individual industries is more sensitive.

more compressed range of work Internet time. We believe that this compression is caused by employees without work-provided Internet using their personal smartphones for work.