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The broadband digital divide and the benefits of mobile broadband for minorities

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Abstract This study sets out the facts regarding broadband deployment and usage in the US and the particular promise of mobile broadband for minorities. Fixed broadband is nearly ubiquitous and most people have access to four or more mobile broadband providers. Growth in fixed broadband usage is leveling off, while mobile broadband usage growth remains robust. Blacks and Hispanics generally have fewer fixed broadband options but more mobile broadband providers available. Gaps in broadband usage overall (fixed and mobile combined) for minorities persist and are quite large. Matching estimators show that lagging broadband adoption among minority groups is not fully accounted for by demographic and economic characteristics. Mobile broadband holds particular promise for minorities regarding healthcare and e-health, and these communities have relatively greater reliance on mobile forms of broadband. Two important findings are that 1) blacks are more likely to access the Internet using a mobile phone than whites (after controlling for demographic differences between the groups), and 2) there is no significant gap in mobile broadband usage between minorities and whites by either of the two measures of usage considered. Implications of the findings for policy toward spectrum allocation and wireless taxes are discussed.

Keywords Digital inclusion · Healthcare · Matching estimator · Spectrum allocation · Technological inequality · Cell phones · Mobiles phones

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1 Introduction

Mobile broadband has substantially changed how people use the Internet. In the US there were 114 million residential mobile broadband connections in June 2012, more than the number of residential fixed broadband connections (FCC 2012). With any new technology, particularly one whose usage is burgeoning as quickly as mobile broadband, differing paces of diffusion among varying groups of the population can lead to inequality of access and usage. This article presents an up to date view of the digital divide facing minorities, showing that significant divides in both availability and usage persist in fixed broadband but not mobile broadband. Broadband technology is especially important for some minorities. Minorities use broadband Internet access to alleviate uneven access to medical care through e-health applications, to take online courses in order to build human capital, and to search for employment. Given the embrace of mobile broadband by minority users and its role in closing broadband access gaps, mobile broadband thus holds significant potential for reducing inequality in minority communities. Therefore public policy affecting the diffusion of mobile broadband technology and service, such as spectrum allocation and taxes targeting wireless communications, is of heightened importance for minorities.

The article proceeds in the next section by examining the state of broadband deployment and usage in the US in general and specifically for minority groups, focusing on African Americans and Hispanics. Both external evidence and a novel examination of Census and FCC data are presented. Data for Internet and broadband usage are from the Computer and Internet Use supplement to the US Census Current Population Survey (CPS), for July 2011. The data on availability come from the US Federal Communications Commission's (FCC) census of all broadband providers in the US as of June 30, 2011, the closest match to the vintage of the CPS data.

Fixed broadband is nearly ubiquitous and most people have access to four or more mobile broadband providers (see Section 2.1). Fixed broadband usage continues to grow in general, albeit at a slowing rate, while mobile broadband growth is robust with no signs of leveling off yet (Section 2.2). Compared to whites, minorities generally have fewer fixed broadband options but more mobile broadband providers available (Section 2.3). Gaps in broadband usage overall (fixed and mobile combined) for minorities persist and are quite large. Matching estimators presented in Section 2.4 show that lagging broadband adoption among minority groups is not fully accounted for by observed individual and household demographic and economic characteristics.

The particular promise that mobile broadband may hold for minorities regarding social, medical, and economic inclusion is discussed in Section 3.1. Compared with whites, these populations have a greater reliance on mobile forms of broadband (Section 3.2). While blacks are less likely overall to access the Internet using a mobile phone than whites, after balancing the covariates between whites and blacks the latter group is slightly more likely to get to the Internet via mobile phone. On the other hand, Hispanics are less likely than whites to access the Internet using a mobile phone. However, there is no significant gap in mobile broadband usage between minorities and whites by either of the two measures of usage considered, either before or after controlling for other demographic and socioeconomic characteristics of the individuals. However, the quality of the official data on mobile broadband usage is lower than that for fixed broadband usage, which limits the extent to which distinctions in mobile broadband usage among racial and ethnic groups can be discerned. The concluding section turns to some policy implications of the findings.

2 The state of broadband availability and usage in the US

In this section, statistics on broadband availability and usage are presented, with emphasis on mobile broadband.

2.1 Availability

As has been true for several years at least, almost everyone in the US lives in areas where fixed broadband connections are available. The FCC Form 477 broadband data for mid-year 2011 indicate that only 0.11 % of individuals live in Census tracts lacking any form of fixed broadband access with transmission speeds of at least 200 kbps in one direction. These fixed broadband access options include DSL, cable modem, satellite, and the relatively rare broadband over power lines (BPL) and fixed wireless sources. An important caveat regarding the FCC data is that there is no guarantee that a broadband provider offers service in the entire tract, which may be problematic in rural areas where tracts are larger.[1] Even when the definition of broadband from the National Broadband Plan (NBP) is used instead (at least 3 mbps downstream and 768 kbps upstream (FCC 2010), only 1.5 % of US residents live in Census tracts lacking fixed broadband access.[2] Given the near ubiquity of fixed broadband access options in the US, the rest of this section focuses on the availability of mobile broadband.

The same data from the FCC show that most areas and almost every individual have access to mobile broadband. Figure 1 is a map of the number of mobile broadband providers in the US by Census tract from the FCC data for June 30, 2011.[3] Darker areas on the map have a greater number of mobile providers in the area. The map shows that most areas have one to three mobile broadband providers. Table 1 presents population-weighted statistics from the same data, showing the probabilities of an individual having access to the various numbers of mobile broadband providers.[4] While the map in Fig. 1 shows that most *areas* have one to three mobile broadband providers, Table 1 reveals that most *people* live in tracts with four or more providers.

Figure 2 shows that the prevalence of mobile broadband providers has changed little since the end of 2008 in the US. The median individual in the US resides in a tract that had at least four mobile broadband providers during 2008-2011, and the fraction of individuals living in tracts lacking mobile broadband is too minuscule to be seen in the chart.

[1] Rural tracts average 198.7 square miles (median = 54.8 mi^2), while non-rural tracts average 13.1 square miles (median = 1.2 mi^2). The definition of rural is from the Economic Research Service (ERS) of the US Department of Agriculture. The ERS data categorize tracts based on population density, urbanization, and daily commuting patterns. A tract is considered rural if it has a Census 2000 Rural/Urban Commuting Area code in the range 4–10.

[2] Figures are the author's calculations, using tract population estimates from Geolytics.

[3] All figures for mobile broadband from the FCC data use the FCC definition of 200 kbps transmission at least one way. See Prieger and Church (2012) and Prieger (2013) for similar maps with earlier waves of the FCC data.

[4] In the June 2011 data, 85 % of reported mobile broadband connections were slower than 3 mbps in the downstream direction (FCC 2012). Thus, the FCC data include mobile broadband providers offering relatively slow broadband, but the major wireless carriers in the US are expanding deployment of 4G technology in their service areas.

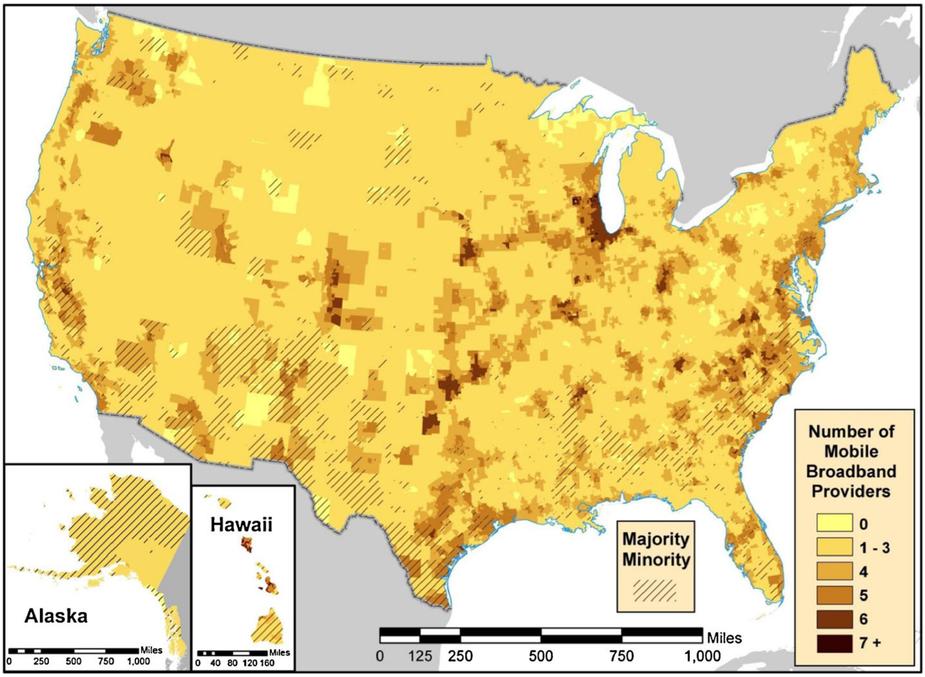

Figure note: Data source is FCC Form 477 for broadband provision as of June 30, 2011.

Fig. 1 Mobile providers of broadband in the US, midyear 2011

2.2 Usage

There has been continuing growth in residential broadband usage ever since official statistics were first collected in 1999 by the FCC. Figure 3 shows that residential fixed broadband connections, which include DSL, cable modem, fiber optic, and fixed wireless connections, have grown from fewer than two million lines in December 1999 to over 82 million in

Table 1 Mobile broadband providers for US population, midyear 2011 (row percentages)

Tract population	Mobile broadband providers						
	0	1–3	4	5	6	7+	Total
≥ 50 % white non-Hispanic	0.3	24.4	37.8	30.4	6.9	0.2	100.0
< 50 % white non-Hispanic ("majority minority")	0.1	6.9	39.6	46.8	6.6	0.0	100.0
Total	0.2	19.3	38.3	35.1	6.8	0.2	100.0

Notes: $N = 65{,}314$. Each cell is the percentage of mobile broadband providers within the row falling into the category given by the column heading. The figures are population weighted. The data are from FCC Form 477 broadband data for June 30, 2011. The FCC definition of broadband is 200+ kbps at least one way

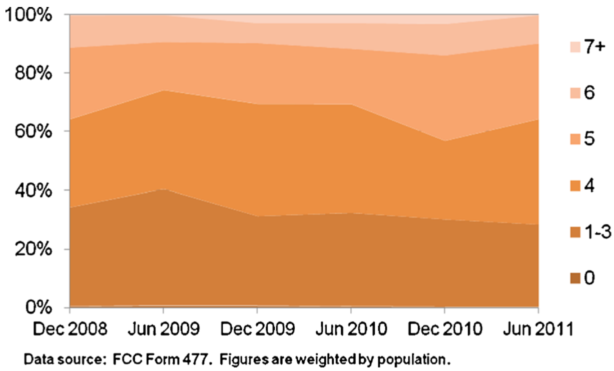

Fig. 2 Distribution of mobile providers of residential broadband, 2008–2011

June 2012, for an annualized growth rate of 31 %. The figures accounting for the increasing population over the period (graphed with dashed lines and scaled according to the right axis in Fig. 3) shows nearly as much growth. Fixed connections per 1000 households rose from 17 in 1999 to 679 in 2012, for a growth rate of 29 % per annum. The implied household subscription rate for fixed broadband of 65.8 % in June 2011 from the FCC data accords well with the evidence from the July 2011 CPS, which yields an estimated household fixed broadband subscription rate for the population of 64.1 % (95 % confidence interval (CI) = [63.76, 64.6]).[5]

As fast as the growth of fixed broadband has been, growth in the provision of mobile broadband has been nothing less than astounding. As recently as June 2005, mobile broadband subscription in the US was a rarity. By June 2011, however, mobile broadband connections outnumbered fixed connections in the US. A year later there were almost 115 million residential mobile connections served. Calculating from June 2006, the first time the FCC reported over a million mobile connections, the annualized growth rate through 2012 of residential mobile broadband subscription averaged 77 %—subscribership roughly tripled every two years on average. In per capita terms, residential mobile broadband rose from virtually nil in 2005 to 365 per 1000 persons in 2012, for a nearly identical growth rate of 76 % per annum. Not only has the growth in mobile broadband outpaced that of fixed broadband, examination of the trends in Fig. 3 reveals clearly that while fixed broadband growth is slowing, growth of mobile broadband only recently reached an inflection point. There is clearly room for much more growth in mobile broadband. While few households would ever consider subscribing to multiple fixed broadband lines, multiple mobile connections per person may be demanded as more personal mobile electronic devices add Internet functionality.

It is difficult to find usage rates in the CPS data that are comparable to the FCC implied mobile subscription rate of 29.8 % per capita in June 2011. Several survey questions in

[5] All estimates from the CPS data are weighted to be unbiased for the US non-institutionalized population. All standard errors are computed with the Taylor series linearization method, account for survey design effects from clustering and stratification, and are robust to heteroskedasticity and clustering within households. The variance estimation takes the survey design approach, where the sampling is assumed to be from a finite population without replacement. Since the CPS does not identify the survey strata, for purposes of variance estimation pseudo-strata were constructed using the method of Prieger and Faltis (2013).

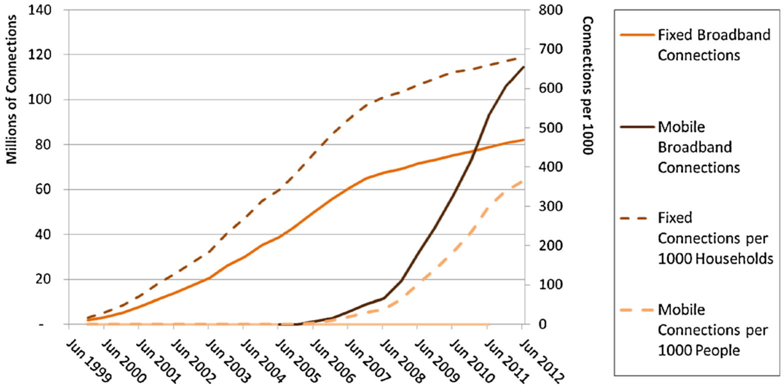

Figure notes: only residential connections are included. Data source: FCC *High-Speed Services for Internet Access* and *Internet Access Services* reports, various years. Population and household figures are from the US Census Bureau.

Fig. 3 Growth in US residential broadband usage, 1999–2012

the CPS are related to mobile broadband. First, the primary household respondent is asked whether anyone in the household uses the Internet from home, including “using the Internet on mobile devices such as smartphones and laptops” (US Bureau of the Census 2012). If the answer is affirmative, the respondent is asked about several types of broadband access, including access to the Internet using a “mobile broadband plan (for a computer, cell phone, smartphone, or tablet).”[6] By this measure, only 8.4 % (95 % CI = [8.1,8.7]) of the population aged 3 and up[7] lived in a mobile-broadband using household in July 2011.[8]

There are two other measures available in the CPS related to mobile broadband. Unrelated to the household mobile broadband question, the following question is asked of each household member (which is answered on behalf of others by the primary household respondent): “Does [the household member] use a cellular or smartphone to access the Internet?” By this measure, a figure exactly matching the mobile broadband subscription rate from the FCC data is obtained: 29.8 % (95 % CI = [29.5,30.2]) of the target population uses a mobile phone to access the Internet.[9] Note that this measure is not restricted to broadband speeds, which in any event are not defined for respondents anywhere in the survey. If the previous measure is refined by counting only persons using a mobile phone to access the

[6]By referring to a “mobile broadband plan,” the wording of the question (if understood correctly by the respondent) should exclude wireless networking within the home from consideration as “mobile broadband.”

[7]The target population of the survey is non-institutionalized US residents aged 3 years and higher, excluding household members in the armed forces.

[8]The estimates here and in the following paragraph are similar but not identical to the final rows of Table 2 (which is discussed below). Here, the population includes those three years old and up, to conform to reports from the National Telecommunications and Information Administration (NTIA) on previous waves of the CPS data. In Table 2, the population is restricted to those who are at least 15 years old.

[9]This variable constructed to measure accessing the Internet through a mobile phone is based on the survey question mentioned in the text but refined in the following way. If the individual stated that he “browses the Web” on his cell phone or smartphone, he is counted as using the phone to access the Internet, regardless of his answer to the direct question given in the text. Only 3.3 % of respondents answering that they did not access the Internet with a mobile phone contradicted themselves by saying they browsed the Web with a mobile phone.

Internet who reside in households with a stated mobile broadband subscription, a usage rate of a mere 4.2 % (95 % CI = [4.0, 4.4]) per capita is obtained.

One additional comparison to external estimates is possible. From the CPS data, the estimate of the proportion of cellphone or smartphone users over 18 years of age in the population that use their devices to access the Internet is 45.7 % (95 % CI = [45.1,46.3]). This figure is similar to a Nielsen estimate for the same month that 40 % of mobile consumers over 18 in the US had smartphones (Kellogg 2011b).

Why are the mobile broadband usage rates from the CPS so much lower than those calculated from the FCC data? At least part of the discrepancy is no doubt due to respondents' confusion over the wording of the survey question. At least until recently, many subscribers probably did not think of their mobile data packages as a "mobile broadband" plan—a term which is not defined for them in the survey. Furthermore, while respondents may know whether they subscribe to a data plan for their mobile phones, many people do not know whether the data plan uses HSPA+, EDGE, LTE, or other network technology, much less which of these qualify as "broadband" under FCC definitions. Survey sponsors and designers would be well advised to think carefully about how to improve the accuracy of information elicited regarding mobile broadband.

2.3 Are minorities are at greater risk of digital exclusion?

In this section, survey evidence from various sources is examined to show that African Americans, Hispanics, and some other minority groups tend to have fewer options for fixed broadband access than whites, but more options for mobile broadband access. Thus, while less access to broadband may play a role in explaining lower minority adoption of broadband overall, the same cannot be said of mobile broadband. The evidence also shows that African Americans and Hispanics are less likely to use broadband (fixed and mobile combined) in the home. While dealing with averages gives the big picture for the various minorities, looking at the groups as a whole should not obscure the fact that there is much variation among individual experiences within the groups. For example, Gant et al. (2010) say that within any particular minority group, those who are younger, more educated, and wealthier tend to be more deeply engaged with broadband.

2.3.1 Broadband access

Disparities in access to and usage of broadband between minorities and others have shrunk or disappeared in recent years. As recently as the beginning of 2010, some data indicated that access gaps may be greater barriers to adoption for minorities. Gant et al. (2010) conducted a national survey of Internet usage in December 2009 and January 2010. When individuals who do not use the Internet were asked why, 13 % of African Americans and 16 % of Hispanics said the reason is that they did not have access. This is the second most commonly given reason, after general lack of interest in the Internet. Only 11 % of whites said their reason for not using the Internet at home was lack of access. There is no longer any difference between whites and Hispanics in these figures, and blacks are now less likely than whites to cite lack of access as the reason for nonadoption. The CPS data for July 2011 show that lack of access (which is defined as the respondent's stated unavailability of broadband *or* lack of an adequate computer to access it) is the main reason stated for not using high-speed Internet at home by about 11 % of non-adopting blacks, 15 % of Hispanics, and 14 % of non-Hispanic whites. The difference between the proportions for Hispanics and whites is insignificant ($p = 0.17$). These figures for blacks, Hispanics, and whites have fallen from about 17 % of non-adopters in each group in the previous wave of CPS data (NTIA 2011, p. 23).

Surveying non-users on why they do not use broadband at home is not the same as examining where broadband connections are available. Another way to examine broadband availability for minorities is to compare the number of residential broadband providers available to a representative member of each racial or ethnic group. Figure 4 depicts the distribution of providers of residential fixed broadband in the US as of midyear 2011. White non-Hispanics have the greatest chance of having four or more fixed broadband providers, at 64 %. Blacks have the lowest probability (46 %) of being in a tract with four or more providers, followed by Asians and Pacific Islanders (49 %) and Hispanics (53 %). If the definition of broadband from the National Broadband Plan (NBP) is used instead (at least 3 mbps downstream and 768 kbps upstream (FCC 2012); results not shown), then white non-Hispanics still have the greatest chance of being in a tract with four or more providers, except for Asians. However, in about 90 % of the tracts the number of providers meeting this higher speed threshold falls into the censored range of one to three providers, it is difficult to compare among the racial and ethnic groups.

The picture is markedly different for mobile broadband provision. The hatching in Fig. 1 shows areas where non-Hispanic whites compose less than half of the population in the tract. Furthermore, given that minorities tend to be concentrated in urban areas, tracts that are "majority minority" (less than half white non-Hispanic, the hatched areas in Fig. 1) have more mobile broadband providers available. That is, the distribution of providers in majority minority areas exhibits second-order stochastic dominance over the distribution in other areas.

Referring to Fig. 5, we see that Hispanics have the second highest likelihood (92 %, after Asians) of having four or more mobile broadband providers and the highest chance of having five or more (52 %). Blacks also have more options that white non-Hispanics, with an 88 % chance of having four or more mobile providers (vs. 75 % for whites) and a 50 % chance of having five or more (vs. 38 % for whites). Other recent research finds evidence from regressions that the more minorities are in the Census tract, the greater the expected number of mobile broadband providers (Prieger 2013). This is probably due to the fact that

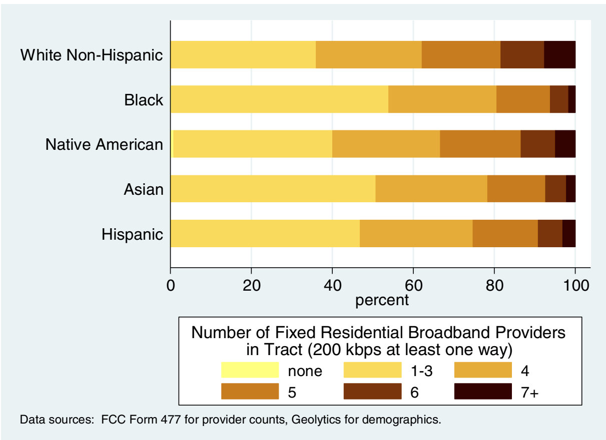

Fig. 4 Distribution of fixed providers of residential broadband by race/ethnicity, midyear 2011

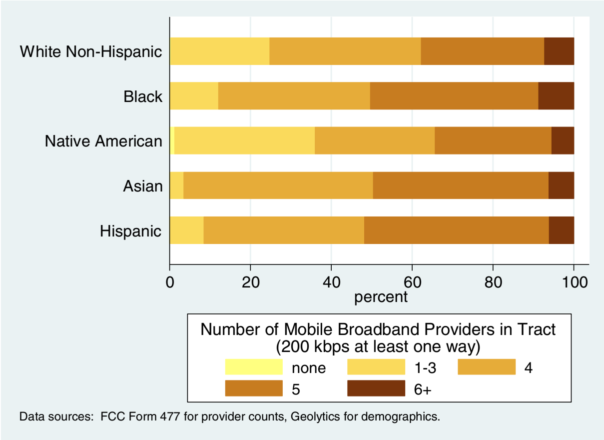

Fig. 5 Distribution of mobile providers of residential broadband by race/ethnicity, midyear 2011

minorities are more likely than whites to live in urban cores, where wireless coverage from multiple providers is usually available.

2.3.2 Broadband usage

Regardless of whether there is unequal access to broadband for minorities, the data show clearly that there are still disparities in broadband usage between minorities and others. A sizable body of empirical literature has explored reasons for lower broadband usage by minorities. Explanations proposed for the broadband gap include lack of computer ownership, low income, and (particularly in earlier years) lack of broadband availability.[10]

In its review of the 2010 CPS figures, the National Telecommunications and Information Administration (NTIA 2011) concluded that when compared with whites, "[s]ignificant disparities …remained among other race and ethnic groups [excepting Asian and white non-Hispanics], with none exceeding broadband use of greater than 50 percent" (p. 11). In October 2010, 50 % of African Americans and 45 % of Hispanics used broadband in the home, but over 68 % of whites and Asian Americans did. The estimates from the CPS for July 2011 for the same population (those aged 3+ years) are nearly identical, meaning that there were no significant adoption gains over the nine month period. This is in contrast to recent growth in broadband use for African Americans and Hispanics as found in CPS data from 2007 to 2009 and from 2009 to 2010. Another recent survey by the FCC from late 2009 shows higher (but still lagging) usage rates for African Americans and Hispanics. The FCC survey (Horrigan 2010) found broadband usage to be 69 % for whites, 59 % for African Americans, and 49 % for Hispanics. The NTIA also found that there could be significant disparities among the sub-groups that make up a racial or ethnic category.

Table 2 contains detailed estimates for broadband usage of various types for the population aged 15 years or older, by race and ethnicity, from the July 2011 CPS data. The first set of columns contains results for personal broadband usage in the home of any sort

[10] See Prieger and Hu (2008) for a review of the literature on minorities and broadband usage and access.

Table 2 Broadband and Internet usage by race and ethnicity, July 2011

	Home Broadband Usage of any Kind		Access Internet on Mobile Phone		Home Mobile Broadband Available		Home Mobile BB Available & Uses Smartphone	
	Proportion [95 % CI]	*p*-value	Proportion [95 % CI]	*p*-value	Proportion [95 % CI]	*p*-value	Proportion [95 % CI]	*p*-value
White non-Hispanic	0.7075		0.3480		0.0826		0.0480	
	[0.703,0.712]	–	[0.343,0.353]	–	[0.079,0.086]	–	[0.046,0.050]	–
Black non-Hispanic	0.5216		0.3343		0.0783		0.0488	
	[0.507,0.536]	0.000†	[0.321,0.348]	0.055†	[0.070,0.088]	0.371†	[0.043,0.056]	0.799†
Native American	0.4856		0.3300		0.1043		0.0521	
non-Hispanic	[0.431,0.541]	0.000†	[0.285,0.379]	0.458†	[0.073,0.148]	0.252†	[0.035,0.078]	0.697†
Asian/Pacific	0.7186		0.363		0.0786		0.0482	
Islander non-Hisp.	[0.699,0.737]	0.268†	[0.344,0.382]	0.129†	[0.067,0.093]	0.554†	[0.040,0.058]	0.956†
Multiracial non-	0.6719		0.3815		0.0847		0.0553	
Hispanic	[0.636,0.706]	0.045†	[0.348,0.417]	0.058†	[0.067,0.107]	0.840†	[0.042,0.073]	0.347†
Hispanic	0.4865		0.2921		0.0782		0.0434	
	[0.473,0.500]	0.000†	[0.281,0.303]	0.000†	[0.070,0.087]	0.327†	[0.038,0.049]	0.121†
Total	0.6524		0.3393		0.0814		0.0475	
	[0.648,0.657]	0.000‡	[0.335,0.344]	0.000‡	[0.079,0.084]	0.583‡	[0.046,0.050]	0.539‡

† *p*-values are for the two-sided Wald test that the proportion for the row subpopulation differs from the proportion for the white non-Hispanic subpopulation

‡ *p*-values are for the Pearson design-based chi-square test for differing proportions among the entire set of subpopulations

Notes: $N = 106{,}744$. All proportions represent estimates for the US population of individuals age 15+. Data are from the CPS Computer and Internet Use Supplement, July 2011 (wired or wireless, fixed or mobile).[11] While overall usage stands at 65 %, white non-Hispanics (71 %), Asians and Pacific Islanders (72 %), and multiracial persons (67 %) all have a greater likelihood of home broadband usage. Hispanics and Native Americans have the lowest usage (49 %), with usage among blacks only slightly higher (52 %). Persistent broadband usage gaps for blacks have been found since the early days of broadband in the home (Hu and Prieger 2009). These findings are generally similar to those of Zickuhr and Smith (2012) from non-governmental surveys.[12] The differences among the usage rates are statistically significant, with the exception that the rate for Asians is indistinguishable from that for whites. Note that these figures do not control for broadband availability in the area. Discussion of the remaining columns in the table, which pertain specifically to mobile Internet and broadband usage, is deferred until Section 3.2.

Although some of the broadband gaps for minorities are caused by lower incomes, income alone does not fully explain the broadband digital divide. For broadband access in particular, the July 2011 CPS data show that among members of households earning less than $20,000, 31 % of blacks and 25 % of Hispanics use broadband at home, compared with 43 % of white non-Hispanics.[13] Similarly, differences in human capital alone do not explain the entire usage gap between whites and non-whites. Among high-school dropouts in July 2011, 23 % each of African Americans and Hispanics used broadband at home, which lags usage by white dropouts (35 %).[14] Gant et al. (2010) also shows that the differential Internet adoption rates of minorities are not explained solely by rural versus non-rural location, for blacks and Hispanics lagged whites in both areas.

In summary, large adoption gaps remain in fixed broadband subscription by race and ethnicity. The gaps in fixed broadband usage for minorities do not appear to be caused by lack of access to broadband in the area, because blacks and Hispanics are no more likely than whites to cite lack of access as the main reason for not subscribing to broadband in the home. However, blacks and Hispanics appear to have fewer fixed residential broadband providers available where they live although virtually all areas have access to at least one fixed provider. On the other hand, African-Americans and Hispanics on average have more mobile broadband providers available where they live than do whites. Thus, mobile broadband appears to hold great promise for connecting minority communities to the Internet where they live. As will be discussed in Section 3.2, evidence indicates that some minority groups indeed rely disproportionately on mobile sources for their broadband connections.

2.4 Matching estimators for broadband usage gaps

An important question is whether differences in demographics among racial groups account fully for differing broadband usage. If, for example, African Americans as a group have lower demand for broadband just because they have lower income, then policy aimed at low income households may be sufficient to encourage adoption among blacks. To explore this question more intensively, it is necessary to control for more than one socioeconomic

[11] The figures are for persons using the Internet from home who are in a household with broadband access.

[12] However, the Pew data these authors examine did not display any disparity in usage between whites and Hispanics. Most likely this is because the Pew survey does not include non-English speaking Hispanics, which may account for the discrepancy between its results and survey results from other sources.

[13] The figures are for persons using the Internet from home who are in a household with broadband access.

[14] Estimates are from the CPS data for individuals 18 years or older who lack a high-school degree or equivalent.

characteristic at a time. To illustrate the econometric issues involved, it is useful to draw on the treatment effect literature. When comparing outcomes between a treatment group and a control group, bias can creep into estimates of the treatment effect from three sources (Heckman et al. 1997). The first source of bias (B1) arises because for some in the treatment sample there will be no members of the control group with comparable values of observed characteristics. This is known as the "common support" problem. The second type of bias (B2) happens when the distribution of the observed covariates differs between the groups. The third source of bias (B3) arises when there are unobserved factors influencing outcomes that differ in distribution between the control and treatment groups.

In the present context, the outcome of interest is broadband adoption, the two groups are different racial or ethnic groups, and the observed characteristics are the sociodemographic data available in the CPS. The unobserved factors include (U1) sociodemographic factors not adequately measured in the data, (U2) unobserved differences in broadband availability, quality, or pricing, and (U3) cultural factors influencing broadband adoption. Removing the first two sources of bias, B1 and B2, will leave an adjusted estimate of the difference in broadband adoption rates between the two groups, where the remaining difference in outcomes is due solely to unobservables. Since we are able to control for an extensive array of observed characteristics, factor U1 is not likely to be important,[15] and we can interpret the difference in broadband usage as stemming from U2 and U3. If we are further able to refine our comparison of individuals between the two groups by comparing only within the same geographic area, then factor U2 is not likely to be important either. Thus we arrive at an estimate of the difference in demand for broadband coming from the "pure group effect", as it is known in the regression decomposition literature.

The two main approaches in econometrics to dealing with bias from sources B1 and B2, both related to imbalance among the covariates, are multiple regression and matching estimators. While multiple regression is the more familiar and commonly applied technique to balance covariates, and has been applied often to broadband adoption (e.g., Prieger and Hu 2008; Flamm and Chaudhuri 2007), it does not correct for bias stemming from B1. To correct for bias B2, regression also requires that the functional form chosen for the conditional mean in the dependent variable be linear in the regressors (or in transformations of them) and otherwise correctly specified. Matching estimators, on the other hand, allow one to enforce a requirement of common support in the comparisons, removing B1.[16] Furthermore, by matching on the propensity scores (the probability of being in the treatment group conditional on the covariates), the need for correct specification of the regression function is removed.[17] The method of propensity score matching (Rosenbaum and Rubin 1983) is thus pursued here, and appears to be the first application of matching methods to investigate broadband digital divides.

[15]The exception to this statement is the impact of primary language spoken when the minority group is Hispanics, as discussed below.

[16]Guo and Fraser (2010) provide an accessible introduction to matching methods for the practitioner.

[17]Since the propensity scores are unknown, they must be estimated, which requires specification of the conditional mean for assignment to the treatment group in terms of the observables in the first step estimation. However, in practice it is not difficult to determine whether the propensity scores have been accurately estimated, since one only need check whether the resulting matched samples are indeed balanced on the covariates. On the other hand, when taking the multiple regression approach instead of matching, it is more difficult ever to know whether a proper regression specification for the outcomes has been chosen.

Propensity score matching proceeds in three steps. First, the likelihood of an individual being in the minority group instead of the white non-Hispanic (WNH) group, conditional on other observed covariates, is estimated to yield a propensity score (PS) for each individual. Second, after discarding observations in the WNH group whose PS's are not in the range of the PS's for the minority group, each minority individual is matched to one or more WNH observations that have similar PS's. Details on the matching procedure are in the Online Supplemental Material. Finally, the difference in the average outcomes (broadband usage, in the present application) between the minority group and the matched set of observations from the WNH group is the estimated "pure group effect" on broadband usage described above.

Given the numerical importance of African Americans and Hispanics in the US, their historical gaps in broadband usage, and the significant attention paid to these gaps by policymakers, we focus on comparing these two groups to non-Hispanic whites. The results of five different matching estimators of the home broadband usage gaps are in Table 3. The estimated population difference between the non-Hispanics blacks and whites in home broadband subscription is 18.6 percentage points (see the first row in the table). This figure is the difference in the subpopulation usage estimates for whites and blacks in Table 2. The estimates of the usage gap calculated by various methods of covariate balancing are in the following four rows of Table 3. Removing biases B1 and B2 lowers the estimate of the broadband adoption gap by one-third to one-half, depending on the matching method. The first three matching methods (one-to-one matching and two variants of kernel matching; see Online Supplemental Material for details) balance on a host of demographic, socioeconomic, and area characteristics, as detailed in the Online Supplemental Material, but do not require matches to be in the same geographic area. Thus, these estimates are still susceptible to bias due to factor U2, unobserved differences in broadband availability, quality, or pricing. The estimates of the gap in home broadband usage between blacks and whites are in the range of 11.9 to 12.7 percentage points, and are statistically significant.

The fourth reported matching estimator, labeled *nearest neighbor matching 2* in Table 3, restricts matches to come from the same survey pseudo-stratum (see footnote 5). The pseudo-stratum is usually the metropolitan area of residence (the core-based statistical area, CBSA), but can also be the county or the remaining part of the state not identified more specifically in the CPS.[18] Therefore, this matching estimator will be less susceptible to bias from factor U2.[19] This estimate of the home broadband adoption gap is smaller, at 9.8 percentage points. The results for the home broadband adoption gap for Hispanics, shown in the rightmost columns of Table 1, are similar. The gap in the population of 22.1 percentage points is reduced by 36 % to 39 % after matching, and again the within-stratum matching estimate yields a smaller gap than the previous methods. Results are similar for the final matching estimator, labeled *nearest neighbor matching 3*, in which observations from

[18]The CBSA is available in the CPS for 81 % of the population and the county is available for 1.3 % of the population. The remaining 18 % of the population takes the state of residence as its pseudo-stratum, which is tantamount to grouping most rural residents in a single group.

[19]However, given the smaller number of available whites for matching within the stratum, the potential for bias due to lower quality matching increases. Despite this potential, however, the confidence interval for the within-stratum matching estimate is not much larger than those for the other methods.

Table 3 Differences in broadband and Internet usage by race and ethnicity

Measure of Usage and Method	Match on	Caliper or Bandwidth	Match within Strata	Non-Hispanic Blacks vs. Non-Hispanic Whites		Hispanics vs. Non-Hispanic Whites	
				Difference (in %age points)	95 % Confidence Interval	Difference (in %age points)	95 % Confidence Interval
Home Broadband Usage of Any Kind							
Unbalanced sample	NA	NA	NA	−18.59	[−20.14, −17.04]	−22.10	[−23.53, −20.67]
Nearest neighbor matching 1	Q-score	0.1	no	−12.74	[−14.48, −11.00]	−14.21	[−15.79, −12.64]
Kernel matching 1	Q-score	0.15	no	−11.94	[−13.40, −10.48]	−13.64	[−14.94, −12.34]
Kernel matching 2	P-score	0.06	no	−12.20	[−13.65, −10.74]	−14.04	[−15.34, −12.75]
Nearest neighbor matching 2	Q-score	0.1	yes	−9.80	[−11.61, −7.98]	−13.38	[−15.08, −11.68]
Nearest neighbor matching 3	Q-score	0.1	yes†	−8.72	[−10.71, −6.73]	−12.73	[−14.54, −10.93]
Access Internet on Mobile Phone							
Unbalanced sample	NA	NA	NA	−1.37	[−2.77, 0.03]	−5.59	[−6.78, −4.39]
Nearest neighbor matching 1	Q-score	0.1	no	1.07	[−0.60, 2.74]	−2.43	[−3.84, −1.02]
Kernel matching 1	Q-score	0.15	no	1.49	[0.18, 2.79]	−2.48	[−3.57, −1.39]
Kernel matching 2	P-score	0.06	no	1.45	[0.14, 2.75]	−2.47	[−3.56, −1.39]
Nearest neighbor matching 2	Q-score	0.1	yes	1.34	[−0.40, 3.07]	−2.02	[−3.62, −0.42]
Nearest neighbor matching 3	Q-score	0.1	yes†	1.72	[−0.14, 3.59]	−3.20	[−4.89, −1.52]

† Nearest neighbor matching 3 excludes strata for which the CBSA or country are unknown

Notes: N = 10,228 Blacks, 12,337 Hispanics, and 76,424 whites. Nearest neighbor method is one to one matching with replacement. Kernel method uses the Epanechnikov kernel. Figures in second column are caliper widths for nearest neighbor matching and bandwidth for kernel matching. All matching methods enforce a restriction of common support, which drops 9 black and 133 Hispanic observations. Confidence interval does not account for first-step estimation error of the propensity or q-score. All estimates use survey weights. NA = not applicable pseudo-strata with unknown CBSA or country are dropped. Most such observations dropped are in nonurban areas. These matching estimates of the broadband adoption for blacks and Hispanics are the smallest of all.[20]

Thus, while controlling for factors like income, education, and geography greatly reduce the broadband adoption gap for blacks and Hispanics, they do not vanish. The remaining gaps would appear to be driven mainly by the pure group effects (factor U3), differences in cultural attitudes toward the perceived usefulness of subscribing to broadband.[21] Such differences among racial groups have been posited (Porter and Donthu 2006) but not generally measured before now in the literature. In fact, the few relevant pure group effects for minorities available in the literature appear to favor adoption, the opposite of the present finding. For example, Mossberger et al. (2003) find that African-Americans, and to a lesser extent, Hispanics, hold more positive attitudes toward information technology than whites, after controlling for income, education, age, and gender.

In the case of Hispanics, lack of proficiency in reading English may also contribute toward the remaining broadband gap, since the matching estimators could not balance on language skills.[22] Fox and Livingston (2007) find that English proficiency is a substantial determinant of home Internet subscription by Latinos in the US. Fairlie (2004) finds that after controlling for income and education, Mexican-Americans in Spanish-speaking households are less likely than both Mexican-Americans in English-speaking households and whites to use the Internet, and concludes that "language barriers limit computer and Internet use among Mexican-Americans."

3 Particular benefits of mobile broadband for urban minorities

This section considers two questions regarding mobile broadband. The first question is how broadband can help minorities to improve their personal lives. The area of healthcare is considered as an example. Available research indicates that broadband in general and mobile broadband in particular can help address disparities in health outcomes and access to healthcare that some minorities face. Whether through enhancing prospects for participation in online health communities or through providing the necessary bandwidth to enable mobile health applications and devices, mobile broadband can facilitate access to better health information and care.

The second question pertains to the role that mobile broadband plays in providing Internet access for minority users. Do minority users in general and African Americans in

[20] If OLS regression is used to compute the gaps in home broadband usage of any kind, when all the variables in Table A1 are included as regressors the gaps for blacks and Hispanics are estimated to be −11.38 (CI = [−12.8,−9.9]) and −14.31 [−15.7,−12.9], respectively (all in percentage points). To make the regression comparable to the *nearest neighbor matching 2 (NNM2)* figures, fixed effects for the strata are included and s.e.'s account for survey design effects. Comparing to the *NNM2* figures, we find that regression mildly overstates both the gaps and the precision of the estimates for blacks and Hispanics. For example, the estimated gap for blacks is 16 % higher with the OLS method, and the width of the confidence interval is 21 % smaller.

[21] Some work has shown that lack of a computer in the household is a barrier to broadband adoption by minorities (Gant et al. 2010; Smith 2010b; NTIA 2011). However, the matching estimators control for income. If a minority household chooses not to own a computer when a white but otherwise similar household of equal income does, that choice is part of the pure group effect affecting broadband adoption.

[22] There are few non-Hispanic individuals with Spanish as their first language, and so this factor cannot be added usefully to the set of covariates on which to balance.

particular rely more heavily than others do on mobile devices for their broadband Internet access? Available recent evidence from the literature, as well as new exploration here, suggests this is so. Mobile phone ownership is much more common among minorities than computer ownership, which helps overcome the hardware barrier to broadband usage. Evidence indicates that some minorities are not only more likely to have mobile Internet-capable devices, they are also more likely to use them to access the Internet. Importantly, black and Hispanic users are just as satisfied as others with their online experiences, or more so.

3.1 Urban minorities and digital connectedness

Digital connectedness has become very important for full participation in the social and economic spheres of human interaction. Broadband, and increasingly *mobile* broadband in particular, are the central components of digital connectedness in modern life. As they gain widespread use, mobile Internet-capable devices help integrate cyberspace and physical space (Kellerman 2010). The more important broadband becomes to society, the greater the potential social cost of failing to connect all Americans. The FCC's National Broadband Plan calls the cost of digital exclusion "large and growing" and goes on to state:

For individuals, the cost manifests itself in the form of lost opportunities. As more aspects of daily life move online and offline alternatives disappear, the range of choices available to people without broadband narrows. Digital exclusion compounds inequities for historically marginalized groups. FCC (2010, p. 129)

The National Broadband Plan goes on to assert that broadband can facilitate the narrowing of social and digital divides, helping "... low-income, minority and other communities overcome other persistent socioeconomic or geographic disparities" (FCC 2010, p. 171). The rest of this section looks at some examples of the role broadband can play in furthering digital inclusion.

3.1.1 Broadband can help overcome disparities

How does broadband help minorities to improve their lives? Academics and advocates have argued that broadband Internet access and other forms of "digital literacy" are highly important. Many programs have been aimed at promoting digital literacy and broadband usage among minorities and other disadvantaged groups. Digital literacy programs often have specific goals such as enhancing employment opportunities, integrating immigrants into civic life, fostering social cohesion and interaction among neighborhoods, or building social and human capital by developing ICT skills in the community (Hilding-Hamann et al. 2009; Hauge and Prieger 2009a, 2010b).

The views of those at risk of ending up on the wrong side of the digital divide are perhaps even more compelling than the opinions of the experts. Survey evidence shows that minorities—more than whites—view a lack of broadband as creating detrimental consequences for themselves. A recent Pew report found that minorities in the US are among the groups that are "most attuned to the need for a home broadband connection" (Smith 2010a, p. 14). When looking for employment, African Americans and Hispanics are significantly more likely than whites (51 % versus 39 %) to say that a lack of broadband access presents a "major disadvantage." Similarly, blacks and Hispanics also view not having access to broadband as a major disadvantage when it comes to getting healthcare information, learning new things to improve and enrich their lives, using government services, and keeping up with news and happenings in the community (Smith 2010a).

Some evidence indicates that minorities use broadband Internet access to remedy deficiencies in human capital. For example, a survey conducted by the FCC found that African Americans are significantly more likely to take online classes than whites by a margin of 37 % to 22 % (Horrigan 2010). The importance of the Internet for finding employment is also greater for African Americans, with African Americans being more likely than whites (83 % versus 55 %) to go online to get information about or apply for a job.

Of course, broadband is not a panacea for social ills, and some proponents are too glib when expounding its benefits. When considering digital inclusion, the availability of broadband is only one element of a set of resources and skills that includes digital literacy, relevancy of online content, and the personal financial resources to embrace available devices and service offerings. Furthermore, convincing measurement of the personal benefits caused by programs to stimulate broadband adoption or digital inclusion is nearly nonexistent (Hauge and Prieger 2009a, 2010b). However, broadband can be an important tool for individuals and policymakers alike. In the remainder of this section, two particular areas that demonstrate the potential of broadband to enrich the lives of disadvantaged users are reviewed: civic engagement and healthcare.

3.1.2 E-health and M-health

Greater broadband access can provide minority individuals greater access to the world of online healthcare—e-health—and its relatively new aspect, mobile health, or m-health. Two of the “socioeconomic disparities” mentioned in the National Broadband Plan afflicting low-income minority communities are access to quality healthcare and health outcomes in general. It is well documented that minorities and low-income Americans receive lower access to and quality of healthcare on average than do whites and members of higher-income households (AHRQ 2011). Worse access to quality healthcare translates into worse health outcomes. Only 44 % of African Americans and 34 % of Hispanics rate their health as very good or excellent, compared with 59 % of whites (CDC 2008).

The nexus of healthcare and mobile broadband has at least two aspects. The first is that users with mobile Internet access participate more in certain forms of healthcare-oriented online media. One study found that people with mobile Internet access are more than twice as likely as those with wired connections to seek health information online (Sarasohn-Kahn 2009). Furthermore, for some diseases, education and self-management is critical to help patients to understand their symptoms and treatment options, and online information can play an important role (Schatell et al. 2006). Johnson and Ambrose (2006) discuss how participation in online health communities for patients with complicated treatment plans can help them understand the regimen by their physicians, increasing the likelihood that they stick with their treatments and heal.

The data from the July 2011 CPS also show that individuals in households using mobile broadband engage in more healthcare-related Internet use than any other group. Table 4 shows results for the four questions regarding health-related Internet use in the survey, broken out by the type of Internet access available to the home. Adults lacking broadband access at home are least likely to research health plans or practitioners on the Internet, or to use the Internet to aid in self-diagnosis of health problems. Individuals with dialup access in the home (about 2 % of the adult population) are about four times as likely as the previous group to engage in these activities. Those with fixed broadband in the home, but not mobile broadband, are about 50 % more likely than dialup users to search for such health information on the Internet, and persons in mobile broadband using households are about ten percent more likely than fixed broadband users. The same general pattern of increasing

Table 4 Healthcare-related Internet use by type of household Internet access, July 2011

	No Internet Access in Household	Dialup Internet Access in HH	Fixed Broadband only in HH	Mobile Broadband in household		
	Proportion [95 % CI]	Proportion [95 % CI]	Proportion [95 % CI]	Proportion [95 % CI]	P-value (vs. Fixed BB)†	Relative incidence‡ (vs. others)
Use Internet to research health plans or practitioners?	0.048 [0.043, 0.053]	0.206 [0.178, 0.233]	0.344 [0.338, 0.351]	0.385 [0.366, 0.404]	0.000	1.527
Use Internet to research health info for self-diagnosis?	0.071 [0.065, 0.077]	0.290 [0.259, 0.321]	0.409 [0.402, 0.416]	0.454 [0.434, 0.473]	0.000	1.488
Use Internet to access medical records or consult doctor?	0.010 [0.008, 0.012]	0.031 [0.020, 0.041]	0.070 [0.066, 0.073]	0.076 [0.066, 0.086]	0.285	1.483
Rely on the Internet for healthcare?	0.035 [0.031, 0.039]	0.143 [0.119, 0.166]	0.264 [0.258, 0.270]	0.306 [0.288, 0.323]	0.000	1.589
Use Internet for any of the above?	0.096 [0.089, 0.103]	0.370 [0.337, 0.403]	0.528 [0.521, 0.535]	0.574 [0.554, 0.594]	0.000	1.476

† p-values are for the two-sided Wald test that the proportion for the mobile broadband subpopulation differs from the proportion for the fixed broadband only subpopulation

‡ Relative incidences are the ratio of the proportion for the mobile broadband subpopulation to the proportion for all other individuals

Notes: $N = 53{,}246$. All proportions represent estimates for the US population of individuals age 18+. Data are from the CPS Computer and Internet Use Supplement, July 2011. The subpopulations are not limited to Internet users usage in the progression from no Internet access to mobile broadband access in the home also holds for using the Internet to access medical records or consult with physicians (the third set of rows in Table 4) and for relying on the Internet for healthcare (the fourth set of rows). When mobile broadband users in 2011 are compared to all other individuals, they are half again as likely to engage in the types of healthcare-related Internet use measured in Table 4 (see results in final column).

The figures in Table 4 suggest that mobile broadband is an important part of the modern healthcare consumer's search and consumption. However, using mobile broadband may be related to unobserved factors such as technology acceptance, proficiency, and interest that are also correlated with searching for and accessing healthcare on the Internet. To at least partially set aside the impacts from other contaminating factors, we present the results from a matching estimator. In addition to the host of demographic covariates used in the matching exercises from Table 3, additional variables included in the propensity score estimation (to proxy for technology acceptance, proficiency, and interest) are indicators for the respondent's industry and occupation and a measure of reliance on the Internet. The latter variable counts how many areas of life the respondent states he or she relies on the Internet for.[23] The method is *nearest neighbor matching 1* from Table 3 and the outcome variable is answering yes to any of the Internet healthcare questions in Table 4. The control group is comprises individuals in fixed broadband only households, as in column 3 of Table 4. When the treated group includes individuals in mobile broadband households, as in column 4 of Table 4, the gap in Internet healthcare usage is 23.9 percentage points (95 % CI = [21.2,26.5]). When the treated group includes individuals in households with *only* mobile broadband, the gap in outcomes is 20.9 percentage points (95 % CI = [17.5,24.3]). Thus we find an interesting result: compared to the unadjusted 4.6 percentage point gap in any form of Internet healthcare usage (reported in the last row of Table 4) between mobile broadband and fixed broadband only households, matching to control for differences in technology acceptance, proficiency, and interest *increases* the gap. The analysis undoubtedly falls short of identifying an unassailably causal link between mobile broadband usage and increased Internet healthcare usage, for there is no experiment in the data. However, the results emphasize that mobile broadband can be an important avenue for the healthcare consumer to find information and care.

To the extent that some minorities rely more heavily on smartphones to access the Internet (as documented below), mobile broadband helps level access to e-health among demographic groups, for as Brodie et al. (2000) found, "once people have access to the Internet, the health information digital divide tends to disappear." African Americans who use mobile phones are more than twice as likely as whites to use mobile health applications on their phones (Fox 2010). Fox also finds that blacks and Hispanics owning mobile phones are more likely than whites to search for health and medical information via their phone, although only the latter comparison is statistically significant.

[23]Nine survey questions are included in the count. These are "do you rely on the Internet for any of the following: 1) working from home or telecommuting? 2) entertainment (such as games, videos, or music)? 3) financial services (such as banking, investing, or trading)? 4) job seeking or job training? 5) education or schoolwork (such as taking a class online)? 6) general information (such as news, weather, sports, maps, or government)? 7) consumer services (such as online shopping, travel, or household services)? 8) on-the-go services (such as finding the nearest restaurant or traffic report)? 9) something else?" For maximum flexibility in the specification of the propensity score, the count variable is treated as a categorical variable. Before balancing, the mobile broadband using sample had significantly higher values of the count than the fixed broadband only sample.

Of course, e-involvement alone does not substitute for medical care from a physician, and there may be some limitations with online healthcare, such as misinformation or inadequate security of personal medical information (Johnson and Ambrose 2006). Furthermore, large-scale studies quantifying specific, measurable benefits from participation in online health communities for individuals, particularly with regard to concrete physical health outcomes, are scarce.[24] However, at least one study finds a positive correlation between better health, personal happiness, and looking online for health information (Cotten and Gupta 2004).

The other aspect of the nexus of healthcare and broadband is the field of m-health medical technology. Clearly, we have seen only the first fruits of this linkage. More and more m-health technology will rely on high-speed wireless networks. The National Broadband Plan mentions m-health applications, devices, and networks that allow "clinicians and patients to give and receive care anywhere at any time." Some m-health applications such as downloading diagnostic data and lab results to smartphones are feasible today, provided adequate mobile network bandwidth is available. Other m-health applications are just coming over the horizon of cost-effectiveness, such as non-invasive personal networks of implanted body sensors. Since some minorities are more likely to live in areas underserved by local healthcare facilities (Kirby 2008; AHRQ 2011), medical technology that allows remote monitoring or otherwise removes the limitations of distance in healthcare may greatly benefit minority communities.

3.2 Some minorities rely heavily on mobile broadband

Mobile broadband is growing as the channel of choice for Internet access for many Americans, particularly minorities (Genachowski 2011). Cost is a major reason for the growing popularity of mobile broadband among minorities, who have lower income than whites on average. Smartphones, which are often heavily subsidized by the service provider, cost less than traditional personal computers while still providing an avenue to the Internet (NTIA 2011). Available statistics support the assertion that minorities are less likely to own computers but more likely to have mobile devices. In July 2011, 85 % of non-Hispanic whites had a desktop, laptop, netbook, notebook, and tablet computer at home, compared to only 68 % of non-Hispanic blacks and 68 % of Hispanics.[25] Gant et al. (2010) and Smith (2010b) also found gaps in computer ownership among minorities. Lower computer ownership among some minorities translates into greater barriers to Internet adoption. In July 2011, not having an adequate computer was the main reason for not using high speed Internet at home for 11 % of non-Hispanic blacks, 18 % of non-Hispanic Native Americans, 15 % of Hispanics, but by only 11 % of non-Hispanic whites. These figures show small improvement over a year earlier (NTIA 2011).

Mobile phone ownership is much more common among minorities than computer ownership. In July 2011, non-Hispanic blacks were 22 % more likely to use a cell phone or smartphone than to have a computer in their household, and Hispanics were 19 % more likely. A Nielsen survey showed that when it comes to smartphones (defined in the survey as mobile phones with "app-based, web-enabled operating systems"), usage is higher among Hispanics (45 %) and African Americans (33 %) than among whites (27 %) (Kellogg 2011a). The same survey showed that among new purchasers of mobile phones, the diffe-

[24] The same criticism does not apply to telemedicine, which numerous studies in the medical literature have shown to be effective for specific healthcare applications (Ekeland et al. 2010).

[25] In this section, all statistics from July 2011 are calculated from the CPS by the author.

Table 5 Mobile phone owners' usage of mobile data applications by race and ethnicity, July 2011

Mobile data application	White non-Hispanic	Black non-Hispanic		Hispanic	
	Proportion [95 % CI]	Proportion [95 % CI]	P-value†	Proportion [95 % CI]	P-value†
Accessing the Internet	0.456	0.475	0.073	0.450	0.485
	[0.449, 0.463]	[0.456, 0.493]		[0.432, 0.467]	
Web browsing	0.371	0.384	0.214	0.362	0.367
	[0.364, 0.378]	[0.365, 0.402]		[0.345, 0.380]	
Playing games	0.221	0.250	0.002	0.220	0.892
	[0.214, 0.227]	[0.232, 0.268]		[0.204, 0.235]	
Accessing social networking sites	0.258	0.280	0.031	0.256	0.798
	[0.252, 0.265]	[0.261, 0.298]		[0.240, 0.272]	
Downloading apps	0.257	0.251	0.542	0.226	0.000
	[0.251, 0.264]	[0.234, 0.269]		[0.211, 0.242]	
Listening to music or other audio	0.234	0.280	0.000	0.261	0.004
	[0.228, 0.241]	[0.262, 0.298]		[0.244, 0.277]	
Taking photos or videos	0.447	0.417	0.003	0.413	0.000
	[0.440, 0.454]	[0.399, 0.436]		[0.396, 0.431]	

† p-values are for the two-sided Wald test that the proportion for the column subpopulation differs from the proportion for the non-Hispanic white subpopulation

Notes: $N = 33{,}674$ whites, 4,503 blacks, and 4,203 Hispanics. All proportions represent estimates for the US population of individuals age 18+. "Accessing the Internet" is defined as discussed in footnote 9. Data are from the CPS Computer and Internet Use Supplement, July 2011. The subpopulations are limited to cellphone or smartphone users rences in smartphone adoption among ethnic groups are even starker. Not only are minorities more likely to have mobile Internet-capable smartphones, African Americans are more than twice as likely as whites to say their cell phone is their preferred device to access the Internet, and Hispanics are 60 % more likely (Gant et al. 2010).

In the rest of this section, the CPS data from 2011 are examined to provide an updated comparison of African Americans and Hispanics with whites regarding usage of mobile phone data applications, mobile Internet, and mobile broadband. The results are in Table 5.[26] In July 2011, the proportion of cell phone users accessing the Internet from their phones was similar among non-Hispanic whites (54 %), non-Hispanic blacks (52 %), and Hispanics (55 %).[27] Similarly, there is no difference among these groups for the more specific activity of "browsing the Web." As recently as 2010, other studies found that blacks and Hispanics were more likely to use their mobile phones to access the Internet (Gant et al. 2010). Several other mobile phone activities are listed in Table 5. African Americans use their phones to play games, access social networking sites, and listen to music or other audio more than whites, but use their phones less to take pictures or video (the latter in contrast to evidence from Smith 2010b). Hispanics listen to music on their phones more than non-Hispanic whites, but are less likely to download apps or take photos or videos with their phones. There are no significant differences among the subpopulations in usage of mobile phones for text messaging, email, or maps and GPS applications (estimates not shown in Table 5).

Returning to Tables 2 and 3, we can examine several measures of mobile Internet and broadband usage among minorities aged 15+ from the CPS data. The first is whether the individual uses a cell phone or smartphone to access the Internet.[28] These individuals do not necessarily have data speeds high enough to qualify as broadband. Mobile Internet usage by blacks is 1.4 percentage points lower than whites (with a p-value for the difference of 0.055), and mobile Internet usage by Hispanics is 5.6 percentage points lower than whites (p-value = 0.000). The mobile Internet usage rates for Native Americans and Asians are not significantly different than that for whites. When conditioning on home broadband use of any kind, however, the importance of mobile broadband for minorities begins to appear. Recalculating the statistics in Table 2 shows that among broadband users, blacks are 13.5 % more likely than whites to access the Internet from their mobile phones (95 % CI = [9.0 %, 17.9 %]), and Hispanics are 7.2 % [3.1 %, 11.3 %] more likely.[29]

Returning to the usage gaps from Table 2 and the first row of Table 3, where the statistics are not conditioned on using broadband, we find that after matching to balance the covariates the usage rate for blacks is again higher than that for whites, by 1.1 to 1.5 percentage

[26]The question regarding cell phone or smartphone use was asked only of primary respondents in the CPS. Statistics cited in this section are for the subpopulation of those answering yes to this question. If household members other than the primary respondent (who tend to be younger) use mobile phones to access the Internet at a different rate than primary respondents, and these differences vary by race, then the statistics here may not be representative of the population of mobile phone users.

[27]This variable is defined as discussed in footnote 9. Unlike the statistics presented in footnote 22, those here are not conditional on using broadband at home.

[28]This variable, defined as explained in footnote 9, is not conditioned on owning a mobile phone.

[29]The figures are calculated from the ratio of the usage proportions for the two groups, and thus are percentage differences, not differences in percentage points. The rest of the figures are: Native Americans are 21.1 % [4.8 %, 37.4 %] more likely, Asians/Pacific Islanders are 5.4 % [0.1 %, 10.7 %] more likely, and multiracial non-Hispanics are 12.5 % [2.8 %, 22.2 %] more likely than whites to access the Internet from their mobile phones.

points. The 95 % confidence intervals for the difference exclude zero for two of the estimates. A third estimate, from method *nearest neighbor matching 3*, is significant at the 10 % level(or at the 5 % level from the hypothesis test against the one-sided alternative that blacks have a higher usage rate). Thus, after matching, blacks are more likely to use their mobile phones to access the Internet than observably similar whites, even without conditioning on broadband usage in the home. Even though the difference in usage rates is not large—blacks are about 5 % more likely than similar whites to access the Internet on their mobile phone—the results here corroborate the evidence from the literature discussed above that mobile devices are an important avenue to the Internet for some minorities in the US. The mobile Internet access gap for Hispanics shrinks from 5.6 percentage points in the unbalanced comparison to 2.0–2.5 percentage points after matching, and remains statistically significant.[30]

The other two measures discussed in Section 2.2 above, the availability of mobile broadband at home and the coincidence of home mobile broadband and smartphone usage, are in the final two sets of columns in Table 2. Black and Hispanic individuals lag white individuals in the availability of mobile broadband in the household, but the differences are too slight to be statistically significant whether tested individually or jointly. After matching, the difference in usage rates remains insignificant (results not shown in Table 3). The same is true of both the unbalanced and matched comparisons for the variable measuring smartphone usage by individuals in households with mobile broadband access.

A criticism sometimes leveled, particularly in the 3G era of mobile Internet access, was that limitations in wireless devices and connection speeds led to a "second class" experience for mobile users. Continual improvement in mobile devices and technology makes this much less of a concern. Smartphones get ever "smarter," and with the latest mobile broadband technology such as LTE, data transmission rates satisfy any official definition of broadband. With the further diffusion of relatively low cost tablets and smartphones, the mobile broadband experience will only get richer (Genachowski 2011). Despite the relatively greater reliance of African Americans on mobile devices to access the Internet, as a group blacks are even more satisfied with their online experiences than others. Gant et al. (2010) find that 65 % of African American Internet users responded that they are "very satisfied" with their broadband service, compared to 61 % of Hispanics and 57 % of whites. At the other end of the spectrum, African Americans are less likely than others to report that they are either "not too satisfied" or"not satisfied at all."

Finally, the importance of mobile broadband for minorities can also be seen from examining the reasons why households do not have broadband in the home. In July 2011, 14.1 % of households that do not subscribe to broadband say they do not because broadband is unavailable.[31] Among such households, Fig. 6 shows what type of unavailable broadband is the perceived barrier to access. The figure shows that blacks are more than twice as likely as whites (12.3 % vs. 5.7 %), Asians are more than five as likely as whites (30.7 % vs. 5.7 %), and Hispanics are seven times as likely as whites (40.0 % vs. 5.7 %) to cite the lack of mobile broadband as the barrier.

[30]When the exercise with OLS regression is repeated as in footnote 20 but with the dependent variable for using a mobile phone to access the Internet, the gaps for blacks and Hispanics are estimated to be −0.47 (CI = [−1.8, 0.9]) and −4.83 [−6.1, −3.5], respectively (all in percentage points). Comparing to the figures from *nearest neighbor matching 2*, we find that regression does not reverse the gap for blacks and yields a much larger gap for Hispanics. As before, regression also overstates the precision of the estimates.

[31]As with all the statistics calculated from the CPS data herein, the figure is weighted to reflect the target population. The 95 % confidence interval is (0.135, 0.148). It is also important to note that the survey did not verify that broadband was unavailable at the location of the household.

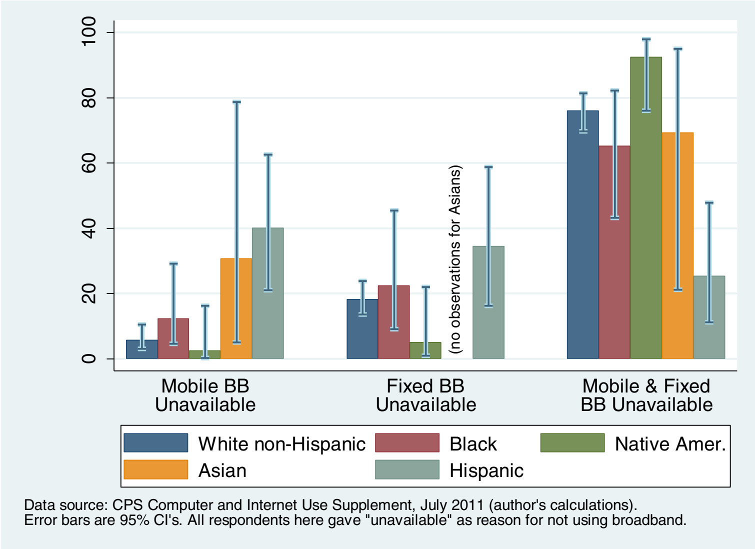

Fig. 6 Type of broadband unavailable among households not subscribing due to unavailability

4 Discussion and conclusions

Two themes arise from the empirical results. The first is an encouraging message for advocates of digital inclusion for minorities. Despite the absence of any large-scale subsidies for broadband,[32] mobile broadband use appears to be at least as high among blacks as among similar whites, while the usage gap for Hispanics is only a few percentage points. The first use of broadband at home for many minorities is mobile Internet access, particularly when lacking a computer in the home. Since recent econometric evidence suggests that fixed and mobile broadband usage is complementary in developed countries,[33] the increasing use of mobile broadband by minorities may lead to narrowing the gap in fixed broadband usage at home as well. The second message highlights the progress yet to be made. Despite strong growth rates in mobile broadband usage, such usage still appears to be far from full diffusion for people of all races and ethnicities. Policymakers interested in stimulating the use of mobile broadband thus have ample scope to do so, although the success of programs designed to encourage broadband adoption remains largely unproven in the literature (Hauge and Prieger 2009a, 2010b).

Nevertheless, as minorities continue to adopt mobile broadband, we should expect the gap in home broadband access between blacks and Hispanics on the one hand and whites on the other to decline. One important caveat regarding this projection is in order, however. The results found here showing that mobile broadband is used as much by minorities as

[32]While the FCC has since added broadband to its list of services supported by the Universal Service Fund, no such federal support was in place in July 2011. At that time, basic mobile telephone service was eligible for partial subsidy from the FCC's Lifeline program for low-income consumers, which would have defrayed part of the total cost of smartphone usage for mobile broadband users.

[33]See Lee et al. (2011), Wulf and Brenner (2013), Jung et al. (2014), and the evidence cited in McDonough (2012). In 2010, in OECD countries, 84 % of people using mobile broadband also used fixed broadband at home.

by whites implies (since blacks and Hispanics have lower income on average) that income effects are not strong in mobile broadband demand. However, if service prices were to rise in coming years, lower income may present more of a barrier to usage for minorities again. Many policies affect the pricing of mobile broadband, directly or indirectly, including antitrust scrutiny of proposed wireless mergers, universal service support for broadband and wireless subscription, and others. Here two other policies related to prices are discussed: spectrum allocation and taxes on wireless service.

While prices (per MB) for mobile data access have been declining,[34] that may change if spectrum scarcity begins to exert upward pressure on service prices. Careful examinations of supply and demand for spectrum show that without additional allocation of spectrum for mobile data usage, demand will outstrip supply at current prices in the near future, creating pressure for service prices to rise (CEA 2012; Clarke 2013; FCC 2013). For that reason, former FCC Chairman Genachowski warned that "[t]he spectrum crunch is a particular concern for minority communities" (Genachowski 2011). While the NTIA and the FCC are in the middle of a ten-year effort to make additional spectrum available for mobile commercial use (FCC 2013), Clarke (2013) warns that the amounts may be too little and come too late, given possible technical or regulatory roadblocks and the 8-10 year lead time required to identify, allocate, and build out spectrum for commercial use. To alleviate such concerns, the NTIA and FCC should move to allocate a greater amount of spectrum to exclusive mobile use sooner rather than toward the end of the ten-year plan.

Other policies that lead to higher prices for mobile broadband access and usage include the myriad special taxes[35] levied on wireless goods and services. For example, many states and localities levy taxes or fees on wireless and other forms of communications services. In California alone, these taxes can create tens of millions of dollars of deadweight loss for consumers (Prieger et al. 2003). Special taxes for wireless communications are widespread in the US: consumers in 46 states face higher rates for wireless service taxes than they do for the general sales tax.[36] Taxes on mobile services are often regressive in nature, and thus disproportionately burden minority and lower-income communities (Turner-Lee and Miller 2011). Limiting the ability of state and local jurisdictions to single out wireless or other communications services (as, for example, the Wireless Tax Fairness Act of 2013 proposes to do) for special taxes may thus be of particular benefit to minorities.

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[34] The cost of data services per MB declined nearly 90 percent from 2008 to 2012. Similarly, the price of wireless service has also fallen every year but one from 2001 to 2011. See Hahn and Singer (2012), who also note that prices for wireless voice and data have never been lower.

[35] Included in the "taxes" discussed here are any taxes, regulatory fees, surcharges, or other assessments levied specifically on wireless communications, however named.

[36] See http://www.mywireless.org/state-issues/ (accessed November 1, 2013).

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