Dynamics of Digital Diffusion and Disadoption: A longitudinal analysis of Indigenous and other Australians

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Abstract

The digital divide between Indigenous and other Australians describes the unequal access to information and communications technology (ICT) between these groups. Historically, researchers have focused on acquiring new technology, but we argue that it is important to understand all the dynamics of digital usage, including the loss of access to ICT within a household. For long-lived technology such as internet access, it is particularly important to consider that retention of access to the technology. This paper conducts a longitudinal analysis of changes in internet usage for Indigenous and non-Indigenous Australian households using the Australian Census Longitudinal Dataset, 2006–2016. While earlier work analyses the digital divide in terms of 'diffusion' or adoption of ICT, this paper shows that the failure to retain internet access is also important in driving the digital divide. The dynamics of the digital divide have important and ongoing implications for addressing broader socioeconomic disadvantages experienced by Indigenous Australians. The COVID-19 pandemic underscores the urgency of policy addressing the digital divide, given the renewed momentum for remote learning and telecommuting.

Keywords: Information and communications technology, digital divide, diffusion, adoption, disadoption, internet access

1   Introduction

A digital divide is evolving in Australian society, with some groups having better access to information and communications technology (ICT) than others (Davis, McMaster and Nowak, 2002, Gurstein, 2004; Daly, 2005). Radoll (2010) identified that the use of ICT is low for Indigenous Australians compared with non-Indigenous Australians. The 2006 Census demonstrated that 43% of Indigenous households had access to the internet, compared with 64% of other households (data accessed using the Australian Bureau of Statistics product Tablebuilder). Given the social exclusion of Indigenous Australians, constraints affecting Indigenous adoption of ICT may have important implications for the ongoing gap in socioeconomic outcomes between Indigenous and other Australians. In the modern world, access to services and knowledge of opportunities to enhance wellbeing are dependent on access to ICT, and hence it is crucial to address the digital divide if gaps in socioeconomic outcomes are to be addressed.

While there are crossectional studies of the digital divide, we argue that it is important to understand how access to ICT changes over time. ICT is inherently dynamic in that the technology and its use vary substantially over time. Furthermore, these manifold changes are

driven by innovations that are not entirely predictable. Rather than attempting to understand these potentially idiosyncratic factors, we focus on the basic infrastructure and overall access to the internet, which is crucial for most forms of ICT. While specific technologies change rapidly, it is possible to conduct a sensible analysis of the dynamics of internet access over a five-year period.

Radoll and Hunter (2017) identified the important role of the processes that lead to the loss of technology or access to technology, which is driven by the failure to reinvest in the face of depreciation, technological or social change, or simply changes in the preferences of people for various forms of technology. In this article we refer to this process as disadoption. Note that disadoption does not necessarily imply some sort of agency from households as it could also involve structural (or infrastructural) issues that policy may have neglected in recent years, including public investment and depreciation.

This study provides the first analysis of the dynamics of internet access of Indigenous Australians using a large-scale dataset that combines the responses from the last three censuses. Radoll and Hunter (2017) used the early release of the Australian Census Longitudinal Dataset (ACLD), which provided information on a substantial number of Indigenous people over a five-year period—information from the 2006 Census on 14 802 individuals who identified as being Indigenous in 2006 was linked with 2011 Census records for the same people (identified through probabilistic matching). The 2016 census data has since been added to the ACLD and this paper provides the first multivariate analysis of the dynamics of internet access for Indigenous and non-Indigenous households.

The remainder of this paper is structured as follows. The next section provides an overview of the current literature on the digital divide and the adoption of ICT, with a focus on issues for disadvantaged groups. The data and method used in this paper are then documented followed by a brief descriptive analysis of the dynamics of internet access by remoteness (defined in ABS 2011). A multivariate analysis of adoption and disadoption is then conducted using the explanatory factors that are both available in census data and identified as being relevant in the literature review. The 2011–2016 ACLD release is used to estimate the factors associated with the change in ICT access. A conclusion sums up the implications of the work that are particularly significant during, and in the aftermath of, the current COVID-19 pandemic.

2   ICT adoption and its opposite, disadoption

A growing body of evidence demonstrates the benefits of ICT adoption to communities, households and individuals. These include access to online services such as government services, educational institutions, electronic health and electronic banking, as well as increased income (Curtin 2001; Arocena and Senker 2003; Allyn and Yun 2005; Daly 2006). Internet access is important in the context of the digital divide evident between Indigenous and non-Indigenous Australians because it underpins the ability to adopt and use much of the latest ICT.

Quality, access, coverage and use of ICT are critical for participation in Australian society. ICT forms the basis of much economic activity, and not having access to ICT has a clear detrimental economic and social impact. Along these lines, Radoll (2010) shows that some Indigenous individuals and households may be excluded from ICT access because of location, education, economic position or culture.

The term 'adoption' is used in the information systems discipline to describe the uptake of ICT. Specifically, adoption pertains to the 'decision to make full use of an innovation as the best course of action available' (Rogers 1995:21). One relevant contribution in the context of this paper is Rice and Katz (2003) who examined the digital divide in internet and mobile phone usage in terms of adoption and dropouts (also, see Katz and Rice 2002; Rice and Pearce 2015).

Another widely used term in the literature is 'diffusion': 'the process by which an innovation is communicated through certain channels over time among the members of a social system' (Rogers 1995:5). More formally, Rogers refers to the diffusion of innovations theory (DOI).

There are several other theories that may help explain the digital divide between Indigenous and non-Indigenous Australians (Radoll, 2010): theory of reasoned action (TRA; Ajzen and Fishbein, 1980), the theory of planned behaviour (TPB; Ajzen, 1991), the model of adoption of technology in households (MATH; Venkatesh and Brown, 2001), the technology acceptance model (TAM; Davis, 1989), and the unified theory of acceptance and use of technology (Venkatesh, Morris, Davis and Davis, 2003). Radoll (2010) also argues that structuration theory of Giddens (1984) has important implications for understanding the digital divide. Theories such as DOI and TAM postulate that perceived ease of use and usefulness are key to adoption, while other theories such as TRA and TPB rely on behaviour and beliefs, which are independent of the 'perceived outcome' of use of the technology (Compeau, Higgins and Huff, 1999).

While many factors are found to affect household adoption of ICT in society (Venkatesh and Brown, 2001, Venkatesh et al. 2003), research is relatively scarce in explaining the low ICT adoption by Indigenous Australian households. There is also little research about how such adoption may change over time. The approach adopted in this paper is to take a step back from the specific use of a particular ICT and focus on the more fundamental questions surrounding the access to its basic infrastructure. We do not deny the importance of evolving use of ICT, but the internet has been around for almost 30 years and is no longer in itself a new technology. Rather, access to the internet underpins the ability to adopt new technology that may be developed.

While diffusion theory is broadly relevant to understanding connection to the internet, some socioeconomic issues need to be considered. The cost of the provision of internet infrastructure is likely to be higher where the cost of living is higher—for example, in remote areas and nonurban areas that are more distant from the major centres of population. Any good or service that is not locally produced, including most ICT installation and maintenance, will be more expensive because of high transport and fuel costs.

In contrast, the ability to maintain internet infrastructure is likely to be associated with the resources available and the incentives to maintain the infrastructure in the face of technological change, changing community norms about adequate internet access and speed, depreciation, and natural wear and tear. Economists believe that incentives to maintain infrastructure are largely driven by who provides infrastructure or owns the infrastructure (Shilling, Sirmans and Dombrow, 1991). The parties who control decisions to maintain the internet are not necessarily the same people who derive benefit from the access. If people access the internet at work, the employer and worker costs and benefits of internet use need to be taken into account. If the internet is provided as part of a community resource funded by a local organisation or government agency, overuse, often associated with common property

resources, needs to be considered. The key issue here is whether there is private or public ownership of infrastructure, and the incentives of users and providers to maintain the internet services in good working order. Hence, internet access can diminish over time if the original funding agency does not adequately reinvest to maintain the infrastructure in working order or the users do not exercise due care in looking after the equipment provided. Even if a political case is made that internet connectivity should be provided to the Indigenous community at a particular point in time, policy needs to take into account who has the incentive to keep the infrastructure in good working order. The internet infrastructure is, by definition, very technical, so if it breaks down considerable expertise is required; it is probable that suitable expertise may not be locally available.

We know from research that the prominent indicators where the digital divide gap is widening most includes those with employment, better incomes and higher education Van Dijk (2005). Ethnicity also plays a role in determining the digital divide (Van Dijk 2005).

The ICT diffusion literature, and information systems literature more generally, tend to focus on the adoption phase of technology. This is understandable because they are attempting to analyse and explain the take-up of innovations that are, by definition, new. However, once innovations are adopted, they need to receive ongoing investment to maintain their usefulness, this concept is technology maintenance. Technology maintenance predicts that "as the poor increasingly have initial in-home and public access to technology, the digital divide will begin to centre on differences in the ability to maintain that access" (Gonzales, 2016, p235). Hence, adoption is only one part of the story; in terms of the dynamics of the digital divide, we need to understand the outcomes and processes associated with disadoption, where households who had access to the internet lose their access to the internet over time.

Van Dijk (2005) argues that when it comes to the digital divide there are broad consequences to consider, stating that we should consider other aspects of the digital divide beyond the more popular motivational aspects. His belief is that access to the internet is essential for people to participate in both the economy and society fully. Van Dijk (2005) highlights clearly that the digital divide is generally related to other societal gaps such a poverty and inequality in education.

Gonzales (2014) demonstrates the importance of the stratification model in terms of addressing the digital divide. Van Dijk (2005) stratification model states that physical access issues persist even when ownership challenges are addressed. Understanding the reasons for disconnection is important as Gonzales (2016) highlights, these reasons include broken hardware, difficulty in paying bills, and having no or limited access to public internet services. One interesting aspect that Gonzales (2014) highlights is that poorer segments of the community are more likely to be "ill and live in fear of crime than wealthier people" (p. 235). Having access to technology for this segment of the population can at times be critical. Mobile phones or cell phones are also an important consideration in the discussion of the digital divide. There is an increasing reliance of small mobile devices on expensive mobile internet plans. Additionally, small devices are often limited in function compared to having access to having access a large screen device in the home (Gonzales, 2014). Nevertheless; increasingly people living in higher income countries have been cancelling landline services and have moved to mobile-only services (Gonzales, 2014).

Van Dijk (2005) argues that the people adopting technology/internet at a higher rate tend to have higher incomes, better education, are younger and are White. Gonzales (2017) also

demonstrates that ethnicity plays are role in digital communications arguing that people of the same race and gender are likely to exchange messages whether that is via email or instant messaging. She also believes that in lower income communities this communication can in fact bring neighbourhoods closer together through building new social ties. The building of community ties through the internet may be particularly important for those who are socio-economically challenged (Gonzales 2017). For example, Mesch (2012) argues that 'minorities and immigrants will be more likely to use computer-mediated communication to compensate for their lack of cultural capital' (p468).

3   Data and method

Census questions are usually asked at a point in time and reported only as cross-sectional data. The ACLD is an important development for the Australian Bureau of Statistics. A 5% random sample of the 2006 Census was linked with the 2011 Census using data linkage techniques to create the ACLD. The ACLD represents less than 5% of the Indigenous population, but nonetheless forms the largest longitudinal dataset of Indigenous Australia currently in existence (ABS, 2013). The 2016 Census data has now been integrated into the ACLD. The 2006-2011 data is used to establish the stylised facts of the digital divide between Indigenous and non-Indigenous Australians, which will be explained using the multivariate analysis of the 2011-2016 ACLD (ABS 2018).

The census household form is designed to be completed by one person on behalf of everyone in their household. Census questions from 2006 and 2011 about internet access are identical and covers access via broadband, dial-up or other modes (including mobile phones, see ABS, 2011).

Many researchers have pointed out the overall trend of increasing identification of Indigenous people in recent statistical collections (Taylor, 2009). However, at an individual level, it is possible that many people choose not to identify in a particular statistical collection. In this paper, we have defined Indigenous status as measured by the 2006 and 2011 censuses.

The analysis in this paper focuses on household-level data because this is the level at which internet access is measured in the censuses. For the purposes of this analysis, the measure of adoption is the percentage of households who did not have internet access in an earlier census but acquired it by the time of the next Census. Disadoption is measured as the percentage of households who had internet access in the earlier census, but for one reason or another lost that access by the time of the next census.

We explore the main factors identified by Radoll (2010) as being associated with ICT diffusion or adoption for individuals, but we can also measure these factors at the household level as this is the level at which internet access is measured in this paper. Employment is measured by the number of members in the household who are working. Education is measured as the highest educational attainment attained by a member of the household. Remoteness, and household composition and income are also measured at the household level by definition, and hence there is a consistency in the level of analysis throughout the analysis.

Household income is equivalised using the 'modified OECD' equivalence scale, to capture a measure of household resources available after household composition and structure are taken into account (de Vos and Zaidi, 1997). Equivalising is a means of standardising household

incomes in terms of household size and composition so that the relative material wellbeing of households of different sizes and compositions can be analysed.

In practical terms, the process of equivalisation reflects that a larger household needs more income than a smaller household for the two households to have similar standards of living (all else being equal). It also means there are economies of scale as household size increases so that, as the sizes of households increase, the cost per person decreases. The 'modified OECD' scale assigns the first adult a cost value of 1.0, the second and subsequent adults a cost of 0.5, and each additional child a cost of 0.3 (or 30% of the first adult). It is not clear what the best equivalence scale is for Indigenous Australians (Hunter, Kennedy and Biddle, 2004), but the OECD equivalence scales are widely used throughout the world and provide a sensible starting point for the analysis.

Radoll (2010) emphasises the role of the Indigenous field, which can be defined as a domain of life over which the agency of Indigenous people is paramount; it involves the interaction of people holding an Indigenous world view motivated by a unique epistemology, ontology and axiology and rooted in an ancient culture and a shared experience of post-colonial Australia. We attempt to encapsulate the concept of Indigenous field is captured in the following analysis using household composition, where we compare households where there are only Indigenous residents with other households (especially where there are only non-Indigenous residents). Note that another important category of Indigenous households where Indigenous and non-Indigenous people live together; this is referred to as 'mixed' households for the sake of brevity (it is also a convention in the literature).

The other explanatory factors included in the regression analysis are standard in socioeconomic analysis using census data (e.g., Hunter, Gray and Crawford 2016). Household composition variables can capture variation in demand for internet services in the dwelling. Household mobility and home ownership and the housing stock variables capture resources available and investment in the household infrastructure.

In order to provide a preliminary analysis that summarise the multivariate relationships we need a binary regression model to predict the marginal effect of various explanatory factors on the probability of experiencing adoption or disadoption (between 0 and 1). A linear regression model (i.e., the linear probability model estimated using OLS) could be used but that is associated with heteroscedastic error variances. While a generalised linear model such as logistic model could be used to address the issue of heteroscedasticity, a probit regression specification can both address this issue and ensure that the errors are normally distributed. The probit model is easiest to think about in terms of a latent variable, Y^*:

$$Y^*_i = \beta X_i + \varepsilon_i \qquad \varepsilon_i \sim \text{Normal distribution } [0,1] \qquad (1)$$

If $Y^*_i >= 0$, $Y_i = 1$ If $Y^*_i < 0$, $Y_i = 0$

Where:

Then Y_i can be viewed as an indicator for whether this latent variable Y^*_i is positive. Y_i is the dependent variable takes on a value of 0 or 1, if observed adoption and disadoption between 2011 and 2016. The model can be used to estimate the probability (between 0 and 1) of adoption and disadoption.

We choose to report the model in terms of marginal effect of various explanatory factors on the probability of a household experiencing adoption or disadoption because it is relatively intuitive. For continuous data the standard deviation of the sample is calculated, and the marginal effects is estimated as the change in probability association with a one standard deviation change around the average. For dummy variables, the change in probability is measured as a one unit change from the omitted category.

The next section describes some important fact about adoption and disadoption between 2006 and 2011 by examining the differing patterns by Indigenous status of household and the disaggregated remoteness status (i.e., from major urban areas to very remote areas). Section 5 then estimate marginal effects from the regression for the whole ACLD for 2011 to 2016 and the Indigenous and non-Indigenous samples (using a broad remoteness indicator).

Indigenous and remoteness status	2006 internet status	2011 internet status			
		No internet (%)	Internet (%)	Total (%)	Population
Indigenous					
Major urban	No internet	34	66	100	70 515
	Internet	8	92	100	86 292
Inner regional	No internet	41	59	100	55 623
	Internet	12	88	100	50 776
Outer regional	No internet	50	50	100	64 737
	Internet	14	86	100	38 446
Remote	No internet	59	41	100	28 807
	Internet	20	80	100	10 175
Very remote	No internet	77	23	100	65 515
	Internet	46	54	100	7 258
All Indigenous (by 2006 internet status)	No internet	52	48	100	285 218
	Internet	12	88	100	192 936
All Indigenous	(unconditional)	36	64	100	478 186
Non-Indigenous					
Major urban	No internet	37	63	100	2 849 706
	Internet	4	96	100	9 297 533
Inner regional	No internet	41	59	100	1 007 134
	Internet	6	94	100	2 295 365
Outer regional	No internet	42	58	100	483 746
	Internet	6	94	100	1 003 017
Remote	No internet	40	60	100	59 995
	Internet	6	94	100	139 283
Very remote	No internet	38	62	100	16 377
	Internet	7	93	100	39 532
All non-Indigenous	No internet	39	61	100	4 416 882
	Internet	5	95	100	12 774 686
All non-Indigenous	(unconditional)	13	87	100	17 191 544

Note: The population in the last column is the estimated residential population residing in Indigenous and non-Indigenous households in the 2006 Census.

Table 1. Changing internet use by Indigenous status and remoteness, 2006–11

4 Internet adoption and disadoption: changing access patterns of access to the internet by remoteness for Indigenous and non-Indigenous Australians, 2006–2011

Table 1 examines the role of remoteness in the prevalence of adoption and disadoption. We expect remoteness to be associated with these processes because lower levels of accessibility mean that access to information is more valuable, but the cost of providing internet services is likely to be substantially higher. Unless the ICT services are provided locally it will be more.

Table 1 is consistent with Radoll's (2010) observation that ICT diffusion is higher in cities and urban areas than in remote areas. The increased access to the internet is highest in major urban areas, where 66% of Indigenous households acquired internet access between 2006 and 2011. This percentage decreases gradually as the residence of the Indigenous households becomes more remote, and only 23% of very remote Indigenous households without internet access in 2006 acquired it by the time of the 2011 Census.

The rate of ICT adoption among non-Indigenous households is similar irrespective of remoteness: it is 63% in major urban areas; while it is slightly lower in regional areas, remote areas have a similar rate of non-Indigenous adoption to that observed in major urban areas (62% of non-Indigenous households in very remote areas acquired internet access between 2006 and 2011). In terms of adoption of internet access, Indigenous households in remote areas are very different from non-Indigenous households in remote areas in that they experience relatively low rates of adoption. One reason may be that Indigenous people are more likely to be found in such areas, especially very remote areas, where the cost of provision is likely to be very high unless costs are completely offset by subsidies.

As indicated above, it is possible that households lose access to the internet in what we call 'disadoption'. Indigenous people tended to have a particularly pronounced loss of internet access in this period, with 8% of Indigenous households in major urban areas who had internet access in 2006 losing it by 2011. The analogous estimate for the non-Indigenous population in major urban areas is only 4%.

The major finding from Table 1 is that Indigenous households were much more likely to experience a loss of access to the internet between 2006 and 2011 as the residence becomes more remote, especially those Indigenous households in remote and very remote areas. For example, 43% of Indigenous people in very remote areas who had internet access in 2006 did not have internet access by the time of the 2011 Census. While the Indigenous subsample of the ACLD is relatively small, the Indigenous rate of disadoption in remote areas is also high at 20%. In contrast, only 7% and 6% of non-Indigenous households in very remote and remote areas lost internet connectivity over the same period. One explanation for the substantial change in internet connectivity in these areas for Indigenous households is the need for reinvestment in household infrastructure over time, which is disproportionately concentrated in poorly maintained housing stock (Memmott et al. 2012). In our opinion it is more likely to reflect a failure to invest in household ICT infrastructure that may have a high rate of depreciation in certain circumstances. In large households embedded in complex kinship networks and communities, 'permanent' householders may look after infrastructure, but the large number of 'visitors' passing through households may not look after the technology as well as the people responsible for its maintenance or those who want to use the internet in the longer term.

The failure to invest in infrastructure in remote areas may be the responsibility of individuals, communities or the government sector. Householders may be personally responsible for access to the internet, and, if adequate resources are available, investment and reinvestment in the latest technological infrastructure is likely to be the individual's responsibility. It has been observed that the main reason for non-Indigenous people living in remote areas is that they have a well-paid job that attracted them to live in the area in the first place (Gray, Howlett & Hunter, 2014). If that is the case, such households will have more resources (wages) to invest in internet access. However, to the extent that employers are trying to attract good workers with the nonwage characteristics of the jobs advertised, access to the internet may also be a necessary part of the remuneration package. The job itself may involve access to the internet at work.

In an Indigenous household, the government and local community are more likely to have played a role in the initial investment in housing infrastructure, which is more communal in nature (Memmott et al. 2012). If Indigenous householders and communities feel less ownership and individual responsibility for that infrastructure, including ICT infrastructure, they may be less inclined to maintain the infrastructure when it breaks down.

Disadoption is largely an Indigenous phenomenon—the highest estimate of disadoption in the non-Indigenous households is lower than the lowest Indigenous estimate for disadoption in Table 1. Irrespective of the reason for the breakdown of the internet infrastructure, it is clearly a substantial concern in Indigenous households, especially in very remote communities. We will return to this discussion in the concluding section. In the meantime, it is necessary to examine some of the factors that Radoll (2010) identifies as being associated with ICT diffusion.

5   Multivariate analysis of adoption and disadoption, 2011 – 2016

The multivariate analysis of adoption and disadoption are presented as marginal effects of the main factors identified in the diffusion literature. The omitted categories for the dummy variables, are: living in major urban area, no household residents changing address in 5 years to 2011, no householders with Year 11–12 completion, a diploma or degree, one family in household, a 'standard' dwelling (i.e., not improvised, caravan etc), no children in the household under 15 years old and the home is not owned by a resident. Given the composition of Indigenous households is potentially significant, the regression of all ACLD households, includes two dummies for Indigenous-only and mixed households and the omitted category is non-Indigenous households. For the regressions that focus on Indigenous households, a dummy is included for mixed households and the omitted category is Indigenous-only households. This informs the interpretation of the marginal effects as the probability of the adoption or disadoption for the reference household is defined by the omitted category (i.e., setting the dummies being set to zero) and assuming continuous data is set to the sample averages (descriptive statistics for the regression analysis are set out in Appendix Table A1).

Table 2 reports the marginal effect on probability of adoption over 2011–2016 associated with factors modelled using a probit specification. Indigenous-only households has the largest effect on adoption of any explanatory factor (26.8 percentage points). Even after controlling for observable information in the census, the gap between Indigenous and non-Indigenous adoption is large, indeed larger than the difference in the prevalence of adoption in the respective populations; 26.8 percentage points see Appendix Table A1). This implies that differences in endowments of Indigenous and non-Indigenous peoples does not explain the

prevalence in the populations. Mixed households have a 5.5 percentage point lower probability of adoption than non-Indigenous households.

	All ACLD households	Indigenous households	Non-Indigenous households
Indigenous-only household	-0.268		
Mixed household	-0.055	0.159	
Lives in regional area	-0.015	-0.049	-0.014
Lives in remote area	-0.088	-0.205	-0.058
Household mobility	-0.017	0.008	-0.018
Highest qualification is degree	0.160	0.159	0.159
Highest qualification is diploma	0.123	0.134	0.122
Highest qualification is Year 11 or 12	0.094	0.103	0.093
Multiple families in dwelling	-0.097	-0.116	-0.092
Non-standard dwelling location	-0.064	-0.113	-0.062
Children under 15	0.148	0.143	0.145
Own home	0.112	0.149	0.110
Equivalised household income§	0.022	0.043	0.022
Number of dependent students§	0.015	0.017	0.014
Number of employed in household§	0.041	0.032	0.041
Number of usual residents§	-0.017	-0.029	-0.016
Number of bedrooms in house§	0.014	0.022	0.014
SEIFA of local area deciles§	0.007	0.015	0.007
Pseudo R^2	0.074	0.159	0.066
Probability of reference household	0.688	0.431	0.696
Concordance statistic	0.678	0.757	0.670
Number of observations	859,730	28,962	830,768

Notes: Marginal effects of dummy variable are the change in probability of adoption associated a change in the variable from 0 to 1, while marginal effects for continuous variables (denoted with a §) are reported as the change in probability associated with a one standard deviation of the respective explanatory factor. All marginal effects in this table are significant at the conventional levels. The concordance statistics (or c-statistic) is a summary of the trade-off for the model between identifying true positives and false positives (model predicting an owner manager or other people to be an owner-manager). C-statistics with values over 0.7 is evidence that the model is adequate or even a good model (Hosmer and Lemeshow 2000: 162). According to these criteria, the goodness of fit of the reported model for Indigenous households are more than adequate, but the non-Indigenous and total regressions are slightly below the threshold for acceptable discrimination.

Table 2. Marginal effects for adoption regression, 2011-16

Given that Indigenous households are very different from non-Indigenous households in terms of adoption, we separately model the respective populations and focus on the two columns on the right of Table 2. Among Indigenous households, mixed households are 15.9 percentage points more likely to experience adoption than Indigenous-only households.

After controlling for observable characteristics, living in remote areas is associated with less adoption among Indigenous households compared to non-Indigenous households living in major urban areas (marginal effect of -20.5% and -5.8%). The difference is also substantial for

the marginal effect for regional areas (-4.9% and -1.4%). Consistent with the results presented in Table 1. Note that this result controls for the socioeconomic status of the local area (through the SEIFA variable) and mobility of household members.

After the effect of Indigenous status and geography, the effect of education on adoption is the next most prominent factor. However, there is very little difference in the marginal effects for the Indigenous and non-Indigenous households, For example, the marginal effect on adoption of having at least one degree level qualification in the household was identical in the Indigenous and non-Indigenous regressions (15.9%).

Similarly having more than one family in the dwelling was associated with around 10 percentage points less adoption in both sub-populations. Living in non-standard dwellings was associated with substantially lower probability of adoption among the Indigenous households (-11.3% & -6.2%). This probably reflects on the poor quality of the housing stock that Indigenous people live in.

Radoll (2010) argues that young people in households can facilitate the process of diffusion or acquiring internet access. Young people tend to be more aware of technological developments, and this may assist in the installation and maintenance of relevant hardware and software. The presence of young people in households can drive higher demand for ICT-related services because the internet provides educational resources, materials and even access to assessments. The presence of children and dependent students certainly have a large effect of the probability of diffusion in both Indigenous and non-Indigenous households. For example, households with children under 15 years old are over 14 percentage points more likely to experience adoption in both populations.

If Indigenous people manage to purchase or own their home the probability of adoption is even higher in the Indigenous households than non-Indigenous households. Increasing the number of bedrooms in a dwelling is also associated with higher probability of adoption in both populations. After controlling for other aspects of the housing stock, increasing the number of usual residents in a dwelling reduces the probability of adoption. This may reflect the complexity of organising and maintaining large households. Addressing housing shortfalls in Indigenous communities is crucial for addressing the digital divide.

Adoption increases with equivalised household income for both Indigenous and non-Indigenous households. A one standard deviation increase in income increases adoption by more for Indigenous households (4.3% & 2.2%).

Increasing the number of employed in the household increases the probability of adoption. This is true even after controlling for equivalised household income, which may indicate an increased demand for internet access associated with modern jobs to stay connected with work after hours.

As noted above, the rate of disadoption is higher for Indigenous households than non-Indigenous households. Appendix Table A1 shows that in the ACLD twice as many Indigenous households are twice as likely to lose internet access between 2011 and 2016 compared to non-Indigenous households (7.7% versus 2.9%). After controlling for observable characteristics of the household in the ACLD, marginal effect of living in an Indigenous-only households is 1.3 percentage point lower disadoption than for non-Indigenous households (Table 3). The marginal effect on disadoption of living in a mixed household is not significantly different from zero. Hence differences in the size, composition and types of households

explain some of the differences between Indigenous and non-Indigenous households. Again, the regression models are estimated separately for Indigenous and non-Indigenous households.

	All ACLD households	Indigenous households	Non-Indigenous households
Indigenous-only household	0.013		
Mixed household	0.002	-0.027	
Lives in regional area	0.001	0.016	0.000
Lives in remote area	0.004	0.043	0.001
Household mobility	-0.004	-0.014	-0.003
Highest qualification is degree	-0.010	-0.033	-0.009
Highest qualification is diploma	-0.005	-0.018	-0.004
Highest qualification is Year 11 or 12	-0.003	-0.009	-0.003
Multiple families in dwelling	0.006	0.010	0.005
Non-standard dwelling location	-0.002	‡0.014	-0.001
Children under 15 in household	-0.012	-0.042	-0.010
Own home	0.000	-0.011	0.000
Equivalised household income§	-0.011	-0.026	-0.011
Number of dependent students in household§	-0.013	-0.008	-0.014
Number of employed in household§	-0.011	-0.009	-0.011
Number of usual residents§	-0.002	‡0.002	-0.003
Number of bedrooms in house§	-0.003	-0.005	-0.003
SEIFA of local area deciles§	-0.005	-0.017	-0.005
Pseudo R^2	0.300	0.177	0.310
Probability of reference household	0.006	0.038	0.005
Concordance statistic	0.907	0.818	0.910
Number of observations	859,730	28,962	830,768

Notes. See notes for Table 2 above. The probability of the disadoption for the reference household is defined by the omitted category (i.e. setting the dummies being set to zero) and assuming continuous data is set to the sample average. All marginal effects in this table are significant at the conventional levels unless otherwise indicated. ‡ denotes not significant at the 10% level. According to Hosmer and Lemeshow (2000: 162), C-statistics with values over 0.8 indicate an excellent model and values of ≥0.9 to show outstanding discrimination between observations at different levels of the outcome.

Table 3. Marginal effects of disadoption, 2011-16

Geographic variables are again a very significant factor explaining patters in disadoption among Indigenous households, especially living in remote areas (4.3%). While disadoption is also higher for non-Indigenous households outside major urban areas, the marginal effects are relatively small for that population (only 0.1%).

Disadoption is concentrated in households with a low level of resources. Higher Income and living in good neighbourhoods (i.e., with higher socioeconomic status measured by SEIFA) is associated with significantly lower probability of disadoption. This is consistent with the assertion that access to resources is a major reason that internet access is lost, particularly among Indigenous households.

Like the results reported for income, there is a strong association between disadoption and education among Indigenous households. Indeed, the marginal effect of having someone in the household with a degree is associated with a -3.3 percentage point lower probability of disadoption,

Having young people in a household may increase the demand for internet access (i.e. for adoption), and the presence of dependents (both children under 15 and students) is associated with significantly lower rates of disadoption. The marginal effect on disadoption of having children under 15 in the households is particularly pronounced for Indigenous households (4.2% versus 1.0%).

Other measures of housing stock and household composition have a relatively small impact on the probability of disadoption. For example, the effect of living in a non-standard dwelling has no significant effect on the probability of disadoption. One exception to this observation is the presence of multiple families in a dwelling, which is associated with a 1.0 percentage point higher probability of disadoption among Indigenous households (& 0.5% for non-Indigenous households). Given that such households are relatively common in the Indigenous population, this is likely to play a role in explaining the higher rate of disadoption among Indigenous households, especially in more remote areas (Memmott et al 2012).

6   The ongoing digital divide

This paper has focused on the processes that underlie the ongoing digital divide between Indigenous and non-Indigenous Australians: the processes of internet adoption and disadoption. However, we should also ask ourselves whether the ICT adoption or disadoption documented above led to a systematic change in the digital divide. This research is motivated by 2006 Census data that showed that 43% of Indigenous households and 64% of non-Indigenous households had access to the internet—a differential that implied that more than one-fifth of Indigenous households needed to get access to the internet before there is digital equity in Australia. This section examines how the dynamics of internet access described above have affected this digital divide.

Table 4 reports the access to the internet in the 2016 Census by Indigenous status and Indigenous region. There is some good news in that there has been some convergence in internet access. Access in Indigenous households increased to 75%, whereas it increased to 86% for non-Indigenous households. That is, the digital divide between Indigenous and other Australians fell from a differential of 21% in 2006 to only 11% in 2016. One reason for this is that it gets harder to increase the rate of internet access as that rate approaches 100%. The dwellings remaining without internet access may not want ICT services or may be particularly difficult to provide these services for. This phenomenon is what economists call diminishing marginal returns from investment. Indeed, as Indigenous access to the internet improves, we should expect diminishing marginal returns to become more important (Pearce 1986: 238). The relatively high rates of disadoption among Indigenous households point to potential difficulty in achieving digital equity. Unless the rate at which Indigenous households lose ICT services can be lowered substantially, the digital divide cannot be eliminated.

Indigenous region	Indigenous household (%)	Other households (%)	Digital divide (%)
New South Wales			
Sydney–Wollongong	82.3	88.1	5.8
Dubbo	68.4	76.1	7.7
Northeastern NSW	66.3	76.4	10.1
Northwestern NSW	53.1	72.4	19.3
NSW Central and North Coast	78.8	81.7	2.9
Riverina–Orange	71.2	77.7	6.5
Southeastern NSW	77.3	81.9	4.5
Victoria			
Melbourne	85.4	87.9	2.5
Victoria excl. Melbourne	76.6	80.8	4.2
Queensland			
Brisbane	84.6	88.5	3.9
Cairns–Atherton	64.9	84.0	19.1
Cape York	67.1	81.8	14.7
Mount Isa	58.2	84.1	25.9
Rockhampton	75.4	81.2	5.7
Toowoomba–Roma	71.3	79.9	8.7
Torres Strait	68.2	89.0	20.8
Townsville–Mackay	71.7	83.6	11.9
South Australia			
Adelaide	77.0	83.3	6.2
Port Augusta	52.3	74.5	22.2
Port Lincoln–Ceduna	62.0	79.3	17.3
Western Australia			
Perth	79.4	89.0	9.5
Broome	61.3	88.6	27.3
Geraldton	57.4	82.1	24.7
Kalgoorlie	55.5	84.4	28.9
Kununurra	39.6	84.8	45.2
South Hedland	61.4	91.2	29.8
Southwestern WA	69.6	83.2	13.5
West Kimberley	47.3	85.0	37.7
Tasmania			
Tasmania	78.8	80.1	1.3
Northern Territory			
Darwin	74.4	88.9	14.5
Alice Springs	63.2	87.8	24.7
Apatula	27.5	78.2	50.7
Jabiru–Tiwi	53.2	81.6	28.4
Katherine	47.8	83.9	36.0
Nhulunbuy	55.7	90.5	34.8
Tennant Creek	45.5	83.8	38.3
Australian Capital Territory			
ACT	88.1	91.9	3.8
Total Australia	**75.3**	**85.8**	**10.5**

Table 4. Internet access in 2016 by Indigenous household status and Indigenous regions

Table 4 illustrates that the dynamics of internet access lead to a larger digital divide in more remote regions. The table is grouped into regions within states and territories, with the first region in each group being the capital or most urban region. Where a region is dominated by a city with more than 100 000 residents, the digital divide is less than 10 percentage points. As a region becomes more remote, the digital divide tends to increase. The largest differential between Indigenous and non-Indigenous internet access is in Apatula, where the digital divide is more than 50 percentage points. It is not that the internet access of non-Indigenous households is particularly high in these remote regions; rather it reflects the particularly low level of internet access in Indigenous households in remote areas.

7   Concluding remarks

This paper pinpoints several factors associated with Indigenous households being connected to the internet and hence having access to ICT: remoteness, income or access to resources, employment, education, the housing stock and demography (including household composition). The internet is crucial for ensuring adequate connection to services and society. Resources, such as household income, are identified as being important in ensuring that Indigenous people have access to the internet and maintain access to ICT over time. The analysis also identified disadoption as an important policy issue that will potentially lead to further social exclusion of Indigenous Australians. Ensuring Indigenous households have access to resources and an adequate housing stock are of paramount importance for dealing with the digital divide between Indigenous and non-Indigenous households.

It is always salutatory to ask the 'so what' question: are these observations important in the long run? For example, increasing decentralised access to the internet through mobile services may be reducing the significance of relatively fixed household infrastructure. While there may be some truth in this observation, it would be a mistake to ignore the role of fixed infrastructure, because mobile devices generally have more limited functionality than desktop devices, and mobile internet connectivity can often be much slower and more strongly affected by the environment and surrounding infrastructure. Notwithstanding these reflections, mobile internet access is arguably captured in the above census analysis, albeit at the household level.

This paper identifies some information that can be further analysed using panel techniques to control for unobserved heterogeneity between households. Unfortunately, census data are collected at five yearly intervals that makes is difficult to conduct a truly longitudinal analysis when there are so few waves of data (and where the technology is evolving rapidly over time). Identification of the characteristics of households associated with ICT adoption and disadoption would place policy makers in a better position to target their policies appropriately and bridge the digital divide.

One important caveat to our analysis is that our analysis does not directly include community-based access (libraries, internet cafés, etc.), where people without access in their household are nonetheless able to access the internet. However, the SEIFA variable may control for some local public goods, if community resources or access are associated with average local income and socioeconomic status. Community-based access may be an important avenue for public investment, especially after social distancing injunctions associated with the COVID-19 pandemic are no longer necessary.

Radoll (2010) identified 'structure' and 'agency' as key features of the Indigenous household ICT adoption process, especially in the intersection of the employment and education (structures) with Indigenous agency. Using these concepts of structure and agency, the theory asserts that the intersection of the Indigenous field and other factors associated with ICT adoption, along with the interactions between structures and agency, produces new practices by Indigenous agents that lead to Indigenous household ICT adoption. Most of the factors identified above are 'structural' in nature, with the possible exception of the household composition by Indigenous status. It is difficult to analyse issues associated with agency of individuals and households using quantitative techniques, hence it is important for the regression analysis in this paper to be supplemented by qualitative analysis that can attempt to understand the reasons for decisions for adoption or perhaps even unpack the complex factors associated with the failure to make decisions that led to disadoption. The main contribution of this paper is to identify some factors contributing to the digital divide, but policy also needs to understand what determines household outcomes and characteristics.

A comprehensive policy solution needs to be developed to stem the gap of the growing digital divide (Dijk, 2005). Technology maintenance strategies are required to ensure that the Aboriginal and Torres Strait Islander communities are able to maintain their internet connections. The COVID-19 pandemic underscores the urgency of addressing the digital divide. The consequences of not taking immediate policy action will be to further exacerbate the Indigenous disadvantage through constrained access to information and e-services, reduced remote learning opportunities for Indigenous children and exclusion from the labour market that will be increasingly reliant on telecommuting.

Acknowledgement

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Appendix

	All ACLD		Indigenous-only		Non-Indigenous-only	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Adoption	0.675	0.469	0.451	0.498	0.682	0.466
Disadoption	0.031	0.173	0.077	0.266	0.029	0.169
Indigenous-only household	0.012	0.109	0.359	0.480		
Mixed household	0.022	0.145	0.641	0.480		
Lives in regional area	0.270	0.444	0.441	0.496	0.264	0.441
Lives in remote area	0.019	0.137	0.170	0.376	0.014	0.117
Household mobility	0.472	0.499	0.554	0.497	0.469	0.499
Highest qualification is degree	0.355	0.478	0.121	0.327	0.363	0.481
Highest qualification is diploma	0.358	0.479	0.363	0.481	0.357	0.479
Highest qualification is Year 11 or 12	0.137	0.344	0.171	0.376	0.136	0.343
Multiple families in dwelling	0.038	0.192	0.116	0.321	0.036	0.186
Non-standard dwelling location	0.006	0.079	0.004	0.062	0.006	0.079
Children under 15	0.520	0.500	0.724	0.447	0.513	0.500
Own home	0.731	0.444	0.388	0.487	0.743	0.437
Equivalised household income§	1,002	696	660	543	1,014	698
Number of dependent students§	0.240	0.557	0.208	0.491	0.241	0.559
Number of employed in household§	1.650	1.041	1.334	1.116	1.661	1.037
Number of usual residents§	3.570	1.380	4.368	1.765	3.542	1.356
Number of bedrooms in house§	3.382	0.853	3.330	0.839	3.383	0.853
SEIFA of local area deciles§	5.731	2.863	3.579	2.616	5.806	2.842
Number of observations	859,730		28,962		830,768	

Notes. § denotes continuous data.

Table A1. Summary statistics for regressions, ACLD 2011-2016