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A divide quantified—exploring the relationship between ICT infrastructure diffusion and income inequality

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Abstract

Purpose – Information and communication technology (ICT) has the potential to address and reduce income inequality. However, since 1980, income inequality in the United States has caused concerns for researchers, policymakers and the public. Entrepreneurs and managers can take advantage of information technologies, while those in the middle and the bottom see fewer benefits. Meanwhile, countries such as Iceland are more capable of using ICT infrastructure to reduce income inequality, which contributes to the well-being of its citizens. This research study explores the relationship between infrastructure diffusion and income inequality through Rogers's diffusion of innovations theory.

Design/methodology/approach – To answer the research questions, the author assessed the data through a series of regression analyses using SPSS. The authors used Power BI software to chart the relationships between ICT infrastructure diffusion and income inequality by country and in the United States by state and region.

Findings – The results show diffusion of innovations theory's tenets do not necessarily hold, because a significant negative relationship exists between infrastructure diffusion and income inequality, especially in countries with emerging economies. In the United States, this relationship significantly differs by region.

Originality/value – This research contributes to research by expanding economic and sociology work to the IS domain, while providing conflicting evidence for diffusion of innovations theory. The research also provides suggestions for practice, such as more focused ICT infrastructure investments and regulations.

Keywords ICT, Infrastructure, Diffusion of innovations, Internet penetration, Income inequality, Regression, Power BI, Advanced economies, Emerging economies, Global IT report, World economic forum, BroadbandNow

Paper type Research paper

Introduction

Roger McNamee spent 34 years as a technology investor in Silicon Valley, investing in companies such as Facebook. He recently penned an opinion piece in the magazine *Wired,*

Data Availability Statement: The data for this study are available by contacting the corresponding author. We can provide the data in either Excel or SPSS format. The References section contains URLs for many of the data sets and reports.

Disclosure Statement: This article was previously published in the 2020 HICSS conference proceedings. Some of this submission contains the same material, although much of the paper has been expanded and modified. We ran the paper through the TurnItIn plagiarism software, and the similarity was about 56% of the content.

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pleading with 2020 Democratic presidential candidate Joe Biden to ignore leaders' advice in Silicon Valley (McNamee, 2020). According to McNamee, he prefers to avoid advice from CEOs from the information technology (IT) industry because they ignore disinformation, racial and gender bias and the tech industry has become a "poster child" for income inequality.

Building a robust information and communication technology (ICT) infrastructure has many benefits, including creating access to online services for individuals, bridging the digital divide and creating jobs (Gonzales, 2016). Despite these benefits, United States (US) cities with immense innovation and widespread broadband infrastructure, such as cities in Silicon Valley, income inequality is widespread. Individuals in the middle and higher income brackets receive many benefits, while those in lower income brackets struggle to reap the benefits (Berube & Holmes, 2016). In addition, rapid technological change has been destroying jobs faster than it is creating them, leading to inequality in the US (Alderete, 2017; Brynjolfsson & McAfee, 2015). In other words, inherent issues, private and public initiatives, government regulations, policies, etc. may increase inequality, so this research focuses on one specific item among these phenomena: ICT infrastructure availability and its relationship to income inequality.

Rogers theorized as the diffusion of innovations increases, communities may experience an increase in social and income inequality (Rogers, 1995). Cities like San Jose and Mountain View reflect this theory at a surface level. To go beyond anecdotal observation, this research aims to explore the relationship between infrastructure and inequality through three research questions. First, does growth in a country's ICT infrastructure lead to an increase, decrease or no relationship with income inequality? Second, if a relationship does exist, what is the nature of the relationship for countries with advanced versus emerging economies? The US ranks among the top advanced economies for Internet penetration and ICT infrastructure. Unfortunately, the US also ranks among the lowest countries with an advanced economy regarding income inequality (WEF, 2018). As such, the third research question is: how does income inequality relate to infrastructure diffusion within the US?

To answer the questions and present our findings, we first summarize related research on infrastructure diffusion and income inequality. Second, we outline the data sources and analysis methods. Third, we present the results of the analysis. Fourth, we discuss the results in detail. Finally, the paper concludes with a summary of contributions, limitations and future research directions.

Related research

The related research focuses on three fundamental foundations: diffusion of innovations theory, income inequality and the relationship between income inequality and diffusion of innovations.

Diffusion of innovations theory

Diffusion innovations theory (DOI) began with the work of sociologist Everett Rogers in 1962, who defined innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 475). Such innovations, for example the broadband Internet and mobile device usage, may affect individuals, organizations and societies. Rogers identified five general attributes of innovations which consistently influence adoption: relative advantage, compatibility, complexity, observability and trialability.

In the context of ICT infrastructure and its affects, diffusion comprises four main elements, defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, p. 474). The diffusion process tracks these elements as a function of the percentage of adoption over time.

The initial implementation adoption process covers extended periods of time. Once time reaches a midpoint for a technology, the adoption starts to progress, with a steep growth of adoption over a brief time, until the adoption decreases for the last 20–30% of adopters.

Diffusion of innovations theory is now cross-disciplinary regarding research and influencing policy. Policies directed at increasing innovation may make increase the availability for users to adopt innovative technologies (Cozzens & Thakur, 2014). Research on broadband Internet access within countries often extends DOI to ICT adoption. For example, the Korean government implemented regulations and policies to reduce costs and increase competition, which led to an increase in broadband diffusion (Park & Yoon, 2005). But to achieve benefits of ICTs, policy makers often focus too much on availability and affordability instead of user awareness and agency (Kivunike, Ekenberg, Danielson, & Tusubira, 2011) (e.g. usefulness of broadband). ICT plays a major role in socioeconomic development because of government policy, business environment, technology and society (Roztocki, Soja, & Weistroffer, 2019).

Although the origin of DOI theory came from sociology, information systems (IS) research applies the theory broadly. As sociology adoption research typically focuses society, IS adoption research typically focuses on individuals and organizations—as such, DOI has influenced important IS adoption research. Moore and Benbasat expanded the DOI adoption attributes to prescribe eight measures for the adoption and diffusion of innovations: relative advantage, compatibility, ease of use, result demonstrability, image, visibility, trialability and voluntariness (Moore & Benbasat, 1991). The Unified Theory of Acceptance and Use of Information Technology (UTAUT) adds complexity as a predictor of adoption and expands on the Moore and Benbasat measures to include perceptions of IT innovation adoption (Venkatesh, Morris, Davis, & Davis, 2003).

In DOI, laggards adopt a technology later in its lifecycle because of context-dependent factors. For instance, in emerging economies, adoption may be higher when the information usage is relevant to a person's needs, effort is minimal and when the technology is engaging to an individual (Pick, Gollakota, & Singh, 2014).

As DOI is a sociological theory, researchers have extended the theory to integrate innovation characteristics with technology. For instance, the integrated diffusion model integrates DOI with technology-fit theory, finding compatibility, cost, relative advantage and complexity, as well as communication, entertainment and information tasks as significant predictors on the intention to adopt personal IS (Kim & Ammeter, 2014).

Taking sociology research to the enterprise level, studies have extended DOI to on Enterprise Resource Planning (ERP) adoption. For instance, researchers have used DOI to measure the relationship between DOI constructs, satisfaction and organizational performance (Bradford & Florin, 2003) in ERP adoption, finding complexity negatively predicted levels of satisfaction, performance and compatibility.

IS research has also extended also DOI constructs to e-commerce and web technologies. Perceived benefits, compatibility and complexity are all significant predictors of website adoption in organizational settings (Beatty, Shim, & Jones, 2001). In Electronic Data Interchange implementations, relative adoptions, costs and technical compatibility are significant predictors of diffusion (Premkumar, Ramamurthy, & Nilakanta, 1994). DOI even extends to newer emerging and disruptive innovations, such as social media. For instance, organizing vision theory found that community and coherence may significant affect diffusion (Miranda, Kim, & Summers, 2015).

Income inequality

Income inequality is a complex subject, with salient factors, definitions and measurements. One common measure of inequality uses the share of income within a locale (e.g. city, state, country, region and world) going to the top 1.0% or top 0.1% of earners (Jones & Kim, 2018). Socio-economic inequality manifests in many ways—in the context of this study, inequality can decrease opportunity for individuals and populations while decreasing the subjective well-being of individuals (Lohmann, 2015).

In the last 40 years, income inequality has risen slowly in some countries such as France and Japan, but has risen sharply in the US (Jones & Kim, 2018). In society, growth and inequality is a double-edged sword, because as economies grow, inequality may also grow (Panizza, 2002). But slowing economic growth also creates negative outcomes for countries (or cities, states, regions) with increased inequality. Within the US, there has been a negative relationship between income inequality and economic growth, such that as the economy has grown, so has inequality. This negative relationship is not unique to the US—for instance, South America has this negative relationship, such that as inequality increases, economic growth decreases (and vice versa) (Shin, 2012). In countries with emerging economies, growing ICT infrastructures can lead to economic growth, however, this may decrease the number of unskilled jobs which may lead to increased poverty and inequality (Chatterjee, 2020).

One common measure of income inequality is the Gini index of income inequality. The Gini index varies from 0 (i.e. 0%) to 1 (i.e. 100%), with a 1 indicating perfect inequality and a 0 indicating perfect equality (Guzman, 2017). In other words, the lower the Gini index, the lower the level of equality. National and global organizations track the Gini coefficient such as the US census, US Central Intelligence Agency, the World Bank and the World Economic Forum. The world Gini coefficient has decreased in recent years, from 0.80 in 1988 to 0.65 in 2013 (Bank, 2016), which indicates global inequality has decreased. However, some researchers have argued that income inequality has risen sharply in the last few decades, especially in advanced economies (Aghion, Akcigit, Bergeaud, Blundell, & Hémous, 2018), although the underlying factors are uncertain. In the US, inequality grew more than 11% between 1979 and 2005 (Bakija, Cole, & Heim, 2012).

The relationship between innovation and inequality

The relationship between diffusion of innovations and income inequality is a fundamental principle of DOI theory. As innovations diffuse throughout a social system, often the gap widens between higher and lower income groups (Rogers, 2003). In the US, there is a positive correlation between innovation and top income inequality across US states (Aghion *et al.*, 2018; Jones & Kim, 2018). However, studies have also shown ICT adoption may impact human development and remove inequalities and information access barriers (Alam & Wagner, 2016).

Researchers have used DOI and other theories to examine links between Internet penetration in a country and income inequality. But more often, research mostly focuses on the effects of ICT on economic growth rather than inequality (Richmond & Triplett, 2018). The effect of ICTs on income inequality often depends on the type of ICT (e.g. broadband, mobile), the measure of income inequality (e.g. Gini), and other social, economic and government factors (Richmond & Triplett, 2018). As previously stated, Gini is not the only measure of income inequality. One such alternative measure of income inequality is the index of financial inclusion (IFI), which has identified a positive relationship between the growth of ICT use and IFI measures (Sarma & Pais, 2011).

Materials and methods

The first research question asks about the relationship between ICT infrastructure diffusion and income inequality by country. Unfortunately, no single data sets exist with infrastructure diffusion and income inequality, so we obtained and combined data from multiple publications by the World Economic Forum (WEF). The Global Information Technology Report for 2012–2016 provides the ICT infrastructure diffusion data (Baller, Dutta, & Lanvin, 2016). In this report, each IT usage characteristic rates on a continuous scale from 1 (i.e. no infrastructure) to 7 (i.e. perfect infrastructure). For example, Haiti has the worst infrastructure in the data set (1.34) and Iceland has the best infrastructure (6.94).

The Inclusive Development Index for 2018 provides the data on income inequality (WEF, 2018). The WEF uses a net income Gini ranging from 0 (perfect equality) to 100 (perfect inequality). For example, South Africa has the highest inequality in the data set (57.7), while Iceland has the lowest inequality (24.4).

To answer the first research question, we regressed income inequality on multiple IT usage characteristics: business and innovation environment, infrastructure, affordability and individual usage from the Global Information Technology Report. The second research question adds countries with advanced economies to the equation, so we used the type of economy as a control variable in the regressions. Moreover, to view these relationships, we created a series of charts using Microsoft Power BI.

The third research question assesses the relationship between ICT infrastructure diffusion and income inequality in the US. Again, there is no single data set with infrastructure diffusion and income inequality, so we obtained and combined data from multiple sources. The income inequality Gini data came from the US Census Bureau (Guzman, 2017). The Gini index falls on a continuous scale from 0 to 1, where 0 indicates perfect equality and 1 indicates perfect inequality. For example, the state with the highest inequality was New York (0.514), and the state with the lowest inequality was Utah (0.425). The most recent year with *both* Gini data and infrastructure data was 2015.

We used infrastructure data from the US News and World Report (Infrastructure rankings, 2017), which considers the percentage of households with broadband Internet subscriptions along with the share of the state's population with access to high-speed broadband. The report then ranks the states from 1st to 50th. The Census Bureau uses the Gini index, but the World Report uses a ranking system, so we converted the Gini data to ranked data before regressing the income inequality ranking on Internet access ranking by state. We then developed charts in Microsoft Power BI to analyze states that showed interesting relationships between inequality and infrastructure.

Results

From the global perspective, all infrastructure characteristics displayed a significant positive correlation with each other, while displaying a significant *negative* correlation with income inequality. This indicates that as infrastructure diffusion increases, income inequality decreases. See the Pearson correlations in Table 1.

Table 1.
Correlation table

	Income inequality	Individual usage	Infrastructure	Business innovation	Affordability
Income inequality	1.000				
Individual usage	−0.617*	1.000			
Infrastructure	−0.591*	0.952*	1.000		
Business innovation	−0.452*	0.828*	0.839*	1.000	
Affordability	−0.275**	0.552*	0.530*	0.461*	1.000

Note(s): $N = 95$; $^{*}p = 0.000$; $^{**}p = 0.003$

The descriptive statistics are in Table 2, showing inequality and diffusion factors in 2016 overall (emerging and advanced economies combined), by countries with advanced economies, and by countries with emerging economies. Based on the results, advanced countries have less inequality and higher diffusion factors. Another interesting result is the high standard deviation in income inequality in emerging economies, indicating these countries have extremely high or low inequality and diffusion factors, with fewer countries close to the mean.

Next, we regressed income inequality individually on each of the four infrastructure factors. Each factor had a significant *negative* relationship with income inequality. First, we regressed income inequality on individual usage and the model showed a significant negative relationship, $F(1, 96) = 58.942, p = 0.000, R^2 = 0.380$ $\beta = -0.617$. That is, individual usage significantly predicted income inequality, such that as individual usage increases, income inequality decreases. Individual usage accounted for 38.0% of the variance in income inequality.

Second, we regressed income inequality on affordability, and the model showed a significant negative relationship, $F(1, 93) = 7.617, p = 0.007, R^2 = 0.076, \beta = -0.275$. That is, affordability significantly predicted income inequality, such that as affordability increases (i.e. cost decreases), income inequality decreases. Affordability accounted for 7.6% of the variance in income inequality.

Third, we regressed income inequality on business innovation, and the model showed a significant negative relationship, $F(1, 96) = 24.706, p = 0.000, R^2 = 0.205, \beta = -0.452$. That is, business innovation significantly predicted income inequality, such that as business innovation increases, income inequality decreases. Business innovation accounted for 20.5% of the variance in income inequality.

Fourth, we regressed income inequality on infrastructure, and the model showed a significant negative relationship, $F(1, 96) = 51.406, p = 0.000, R^2 = 0.349, \beta = -0.591$. That is, infrastructure significantly predicted income inequality, such that as infrastructure increases, income inequality decreases. Infrastructure accounted for 34.9% of the variance in income inequality.

In summary, the strongest predictors of income inequality were individual usage and infrastructure, and all four factors were significant. Because of this, the answer to research question one is that as infrastructure diffusion factors improve for a country, the income inequality also improves.

RQ2 – countries with advanced versus emerging economies

The second research question assesses the relationship between infrastructure diffusion and inequality in advanced versus emerging economies. To test this, we ran the same regression while controlling for economy type based on the Inclusive Development Index (WEF, 2018).

	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Combined		Advanced (28)		Emerging	
Income inequality	37.33 (98)	7.63	29.70	3.93	40.36 (70)	6.40
Infrastructure	4.23 (111)	1.48	6.05	0.79	3.46 (83)	1.03
Business innovation	4.30 (111)	0.61	4.95	0.39	3.99 (83)	0.51
Affordability	5.15 (107)	1.14	5.62	0.52	4.84 (79)	1.28
Individual usage	3.89 (111)	1.51	5.72	0.63	3.12 (83)	1.07

Note(s): N values in parentheses

Table 2.
Descriptive statistics

See Table 3 for a comparison of the effect of each factor on income inequality while controlling for the type of economy versus not controlling for the economy type.

This comparison shows factors may become less significant depending on whether a country is advanced or emerging. Specifically, infrastructure and individual usage are the only significant relations with income inequality when controlling for the type of economy. All the factors significantly reduce income inequality for a country. However, when we control for the type of economy, the only significant factors are infrastructure and individual usage. To view this relationship, and because the focus of this study is on infrastructure diffusion, we isolated infrastructure and its relationship with income inequality by type of economy. Figure 1 shows this relationship between 2012 and 2016.

This shows two important things in the context of the first two research questions. First, the largest increase in infrastructure for advanced economies—2012–2013—also saw a decrease in inequality overall. Second, the largest increase in inequality—2015–2016—also saw a large decrease in infrastructure growth in both advanced and emerging economies. These two observations reinforce the answer to the first research question, because as infrastructure improved, inequality improved in 2012–2013; in 2015–2016, infrastructure declined, while inequality worsened. Moreover, over the five-year period, infrastructure decreased 1.75% (5.73 to 5.63) in advanced economies but dropped at a greater rate in emerging economies (3.86 to 3.72, 3.63%). Over that time, income inequality grew from 36.39 to 40.10 (9.25%) overall, which helps answer the second research question, that the type of economy plays a key role in the relationship between inequality and infrastructure diffusion. Moreover, emerging economies may be less likely to see the benefits of infrastructure diffusion in relation to inequality, as we observed a higher decline in infrastructure over that time.

Table 3.
Comparing factors with and without controls for economy type

Factor	Standardized beta without control	Significance without control	Standardized beta with control	Significance with control
Infrastructure	−0.591	0.000	−0.244	0.041
Business innovation	−0.452	0.000	−0.052	0.617
Affordability	−0.275	0.007	−0.096	0.252
Individual usage	−0.617	0.000	−0.307	0.010

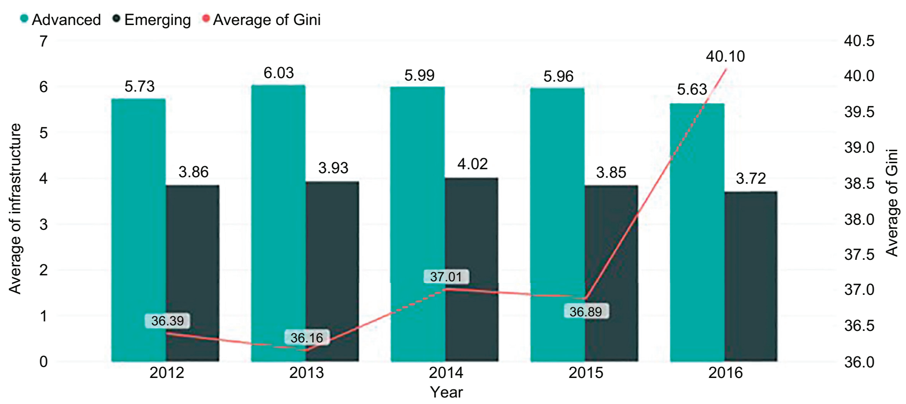

Figure 1.
Average of infrastructure and average of Gini by year and economy type

Data by state in the United States

The last research question explores the relationship between infrastructure diffusion and income inequality within states in the US. The initial correlation and regression induced surprising results. Internet access and inequality by state did not show a significant correlation ($r = 0.138$). We then regressed inequality on Internet access, and the model showed a non-significant relationship, $F(1, 48) = 0.930, p = 0.340, R^2 = 0.019$. That is, Internet access by state did not significantly predict income inequality. Internet access only accounted for 1.9% of the variance in income inequality.

Following these results, we observed the data set and noticed high variance for states in terms of Internet access and inequality. For example, in Alabama, they were among the lowest in both rankings. However, Indiana showed a major difference in the rankings with 42nd in Internet access and 12th in inequality. States in the Southern region were low in both factors, while Western states appeared strong for inequality and Internet access. Because these were anecdotal observations, we tried to verify this empirically by categorizing the states into four regions based on the US Census: South, West, Midwest and East. The average rank of inequality in the South was 32.88 while Internet access was 31.69. The average respective ranks for the East were 30.44 (inequality) and 20.88 (Internet access), 18.54 and 16.00 in the West and 18.25 and 25.58 in the Midwest.

After this observation, we expanded the analysis on state data, because local contextual issues such as limited access to ICTs and inequalities may be relevant (Qureshi, 2014). To do this, we ran a hierarchical regression with two models. Model one regressed inequality on Internet access and we added region to the regression equation in model two. The second model showed a significant relationship, $F(1, 47) = 10.501$, $p = 0.002$, $R^2 = 0.198$. That is, region significantly predicted income inequality above and beyond infrastructure, such that as infrastructure increases in a region, income inequality increases. As such, the answer to this research question is that the evidence shows there is not a significant relationship of income inequality and infrastructure by state, but there is a significant relationship by region. See Table 4 for a summary of answers to the research questions.

Discussion

These results lead to interesting points of discussion. We start by discussing the global results, then the US results regarding the relationship of ICT infrastructures and income inequality.

	Answer	Reason
RQ1: Does growth in a country's ICT infrastructure lead to an increase, decrease or no relationship with income inequality?	Yes, as infrastructure diffusion factors improve for a country, the income inequality also improves	All four factors—individual usage, affordability, business innovation and infrastructure—led to a decrease in income inequality
RQ2: If a relationship does exist, what is the nature of the relationship for countries with advanced versus emerging economies?	Emerging economies may be less likely to see the benefits of infrastructure diffusion in relation to inequality	Infrastructure dropped at a greater rate in emerging economies from 2012 to 2016
RQ3: How does income inequality relate to infrastructure diffusion within the United States?	Internet access and inequality by state did not show a significant correlation or explanation of variance by state but is significant by region	Non-significant correlation and variance between Internet access by state and income inequality. Significant results when assessing region

Table 4. Summary of research questions

Global assessment

We used four factors of ICT infrastructure diffusion in countries—affordability, business innovation, individual usage and infrastructure. All four factors correlated, so we focus this portion on infrastructure and its relation to income inequality. The first research question found an increase in infrastructure diffusions led to a decrease in income inequality, which is the opposite relationship posited by DOI. Using the logic of DOI, only individuals at the top of the income distribution will profit from diffusion, while those in the middle and bottom will not achieve the same income success. Infrastructure investment may increase economic growth through installation jobs, demands for goods and services and network value (Alderete, 2017), but may not improve inequality. Increasing the number of jobs through ICTs is important, as increased ICT usage and appropriation is positively related with an individual's employability (Loh & Chib, 2019).

Income inequality becomes difficult to measure because there are external factors—governmental, cultural, social, technological, etc. We aimed to isolate the social and technological factors by focusing on infrastructure diffusion. While countries experience increased income inequality over time as infrastructure grew, most countries have reduced income inequality over this time (i.e. inequality improved). As such, we will focus on countries with vastly different governmental, cultural, social and technological statuses with differing levels in the relationship between infrastructure diffusion to income inequality—Iceland, Ghana and the US.

Iceland is a model for success of diffusion of broadband infrastructures. 84% of Iceland households received broadband Internet access in 2005, and in 2018 reached 99% (Statista, 2019). The Global Information Technology Report ranks Iceland at or near the top for all network readiness factors. Internet Service Providers (ISPs) often fail to deploy broadband access in rural areas, but the Iceland government engages with rural areas and ISPs to implement broadband infrastructure. Meanwhile, Iceland ranks first in income distribution in the data set. Their combination of capitalist structure and free market principles combined with an extensive welfare system enables this success (Bjorgolfsson, 2018).

Ghana has an emerging economy and experiences a different view of the relationships between diffusion and inequality. Ghana, like other emerging economies, experiences low levels of infrastructure diffusion. Based on research question two, as infrastructure grows, inequality may also grow in emerging economies, albeit more slowly than advanced economies; but their infrastructure according to the Global IT Report ranks 99th out of 111 countries with approximately 13% of individuals having broadband access (ITU, 2016). Meanwhile, their income inequality is average, ranked 54th.

Sources of Gini and Internet diffusion data—such as the World Bank, World Economic Forum, etc.—may use different methodologies, so their ratings often vary. These inconsistencies make it difficult to find consistent data over time. To create a view of the relationship between income inequality and diffusion over time, we charted income inequality data with Internet penetration data from the World Bank (see Figure 2–4). In each chart, the y-axis on the left indicates Gini and the y-axis on the right indicates Internet penetration percentage, with year on the x-axis.

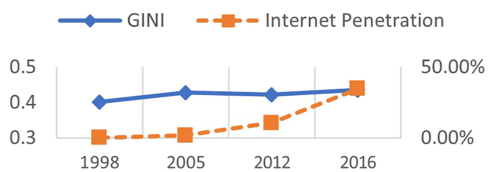

Figure 2.
Relationship of Gini to Internet penetration in Ghana, 1998-2016

The three figures show relevant characteristics regarding the relationship of inequality and Internet diffusion. DOI charts a curve over time that starts slow, rises sharply during the middle time of the diffusion, and then flattens as adoption wanes. Iceland and the US display a similar Internet penetration curve. Ghana displayed moderate growth from 2005 to 2012, and then growth increased sharply to 2016, due to the diffusion of mobile phones. It will be interesting to see the growth trend over the next few years whether it flattens or remains strong, but we do not have data on this yet.

Second, the shape between Gini and Internet penetration shows different patterns for each of the countries. The ratio of Gini to penetration skewed toward higher Gini in Ghana. In 2016, that ratio was smaller, with Gini growing slightly and Internet penetration growing immensely. Over this time, Iceland's relation looks completely different. Gini decreased slightly, while Internet penetration grew steadily. In recent years, the pattern between penetration and Gini diverges.

Iceland's penetration is almost 100%, so it will be interesting to see how Gini changes over the coming years, because penetration will remain stagnant. Their government investments in infrastructure, regulations, and competition are more mature than other countries, so Iceland will be performing maintenance and upgrades rather than initial implementation. This may affect important antecedents to increasing infrastructure and reducing inequality such as fewer installation and development jobs as well as suppressing new infrastructure market entrants. Iceland is not unique with strong Gini and Internet use, as Scandinavian countries, such as Sweden, Finland and Norway are among the top countries.

The US chart also looks different, which may reflect the economic environment in the country. In the great recession of 2008, the chart shows a sharp growth in income inequality, with a slight uptick in Internet penetration. Both Gini and penetration dropped slightly following the recession, although both appeared on similar paths through 2016. In summary, the charts display three drastically different paths for each country with the relationship of income inequality to Internet diffusion—Ghana experiences a convergence, Iceland a divergence and the US appears near parallel.

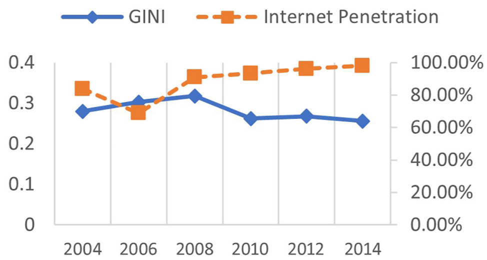

Figure 3.
Relationship of Gini to Internet penetration in Iceland, 2004-2014

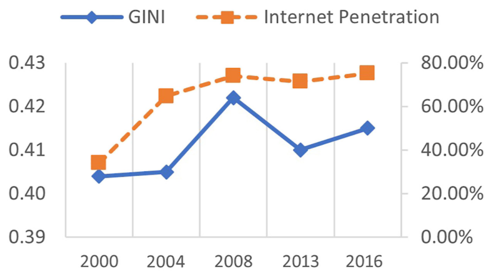

Figure 4.
Relationship of Gini to Internet penetration in the US, 2000-2016

Within the United States

Internet use in the US fluctuated over the last two decades. In 2000, Internet penetration was 43.08%, rising to 75% in 2007, falling steadily to 69.73% in 2011, and then growing steadily to 75.23% in 2017 (Bureau, 2019) (see Figure 4). During this time, Gini experienced extreme changes, but over time remained consistent, as discussed in the previous subsection.

Other countries saw an improvement of income inequality through Internet diffusion. However, despite being an advanced economy, the US did not experience improvement. Among US states, there was not a significant relationship, although region was a significant predictor of this relationship. As such, this subsection will focus first on states, and second on regions. The statistics for this section come from the BroadbandNow initiative (Anderson & Reese, 2019) unless otherwise noted.

The discussion on states will focus on three states with differing inequality and infrastructure outcomes and from different regions. Pennsylvania ranked 29th in both infrastructure and inequality, is in the East region, with a Gini of 0.469 and Internet penetration of 78.2%. As a state near the national average in both these categories, Pennsylvania recognized their poor infrastructure and 650,000 residents who lacked high-speed Internet access, as Governor Tom Wolf announced a "Broadband Initiative," dedicated to providing high-speed Internet to all households and businesses in Pennsylvania (Wolf, 2018). We do not have data yet, but it will be interesting to see how inequality and infrastructure evolves in Pennsylvania, considering this initiative should create jobs while delivering Internet access to homes that currently lack access.

South Dakota ranked 43rd in infrastructure and 8th in inequality. This 35-place difference is the largest difference for infrastructure minus inequality. South Dakota is in the Midwest region, with a Gini of 0.444 and Internet penetration of 79%. Their income equality is strength, although compared to country data, their inequality is still worse than global averages. South Dakota received $6,000,000 in federal grants for broadband initiatives in 2010—since then, their wired connections of at least ten megabits per second improved from 71.1% to 93.9%. Despite this, South Dakota still experiences challenges to Internet adoption, which is typical for rural states.

California ranked 13th in infrastructure and 47th in inequality, which is the largest difference for inequality minus infrastructure (34 places). California is in the West region, with a Gini of 0.488 and Internet penetration of 83.8%. California is a large state with a mix of urban and rural, with startups and technology hubs on the west coast (Silicon Valley and Los Angeles) and farming in the central, northern and eastern part of the state. As of 2020, California had received 10% of *all* federal infrastructure grants, at approximately $350 m. Despite this federal funding for technology, the development has not positively impacted income inequality in California.

When looking at the data by state, the relationship between Internet penetration and Gini does not exist. But when looking at data by region, the relationship between Internet penetration and Gini becomes clear. The South and East regions contain higher income inequality but have less infrastructure diffusion. The West and Midwest experience lower income inequality and greater infrastructure diffusion. See Figure 5 for the average Gini and average Internet penetration by region, which shows the relationship between infrastructure and inequality appears congruent in the South, East and West, while the Midwest may not have a relationship.

Conclusions

To conclude, we will identify limitations of this study, challenges to research in the areas of inequality and infrastructure, future research opportunities and key contributions. One limitation of this study is with the nature of the data. Gini calculations and infrastructure measures differ depending on the source. Annual data also can be inconsistent. For instance, the World Bank contained data every two years between 2004 and 2014 for Iceland on Gini and Internet penetration. Their data on the US comes from 2000, 2004, 2008, 2013 and 2016. This inconsistency becomes difficult to compare countries by year. Moreover, data in emerging economies may be sporadic because of the "data divide," where some national data infrastructures are inferior to more advanced economies (Cinnamon, 2020). Second, income inequality deals with an incredible number of factors which makes it difficult to isolate a single factor or group of factors—be it economic, technology, regulatory, etc. Similarly, isolating specific factors of ICT diffusion is abstract. What constitutes ICT diffusion and adoption? This answer could be broadband infrastructure, mobile infrastructure, desktop use, laptop use, etc.

One of the challenges we have in this research area is access to quality data on these factors. The Inclusive Development Index has not released updates since the 2018 data, and no consistent time-series data exists. At the state level in the US, the data on infrastructure and broadband is difficult to trust, as ISPs have been guilty of over-reporting the broadband diffusion in states (Busby, Tanberk, & Cooper, 2022).

Future research

These limitations and challenges offer fruitful opportunities for future research. First, researchers from multiple disciplines—economics, sociology, political science, IS, education, etc.—can work together to isolate and identify factors and antecedents related to income inequality such as education, computer efficacy, Gross Domestic Product, type of government, social support, taxation, etc. Economics researchers may not be experts in IS use, IS researchers may not be experts in economic principles, so a multidisciplinary study may be useful. Second, researchers may employ a case study methodology to understand successful countries and states and compare them to unsuccessful countries and states regarding income inequality. Researchers could conduct a longitudinal study to view the changes in ICT diffusion and income inequality over time. Third, researchers have criticized diffusion theories and a lack of critical research in ICT for development (Dé, Pal, Sethi, Reddy, & Chitre, 2018). One method of creating critical research on the relationship between technology and inequality would be to combine existing data sets then use rigorous methods to improve the data using *R*, Python, etc. This provides opportunity for collaboration with computer science and business analytics researchers. With improved data, researchers could employ a time-series analysis to understand the relationships over time.

Contributions

Based on the mixed results regarding ICT diffusion and its relationship with income inequality in this study, we offer practical and research contributions. First, one contribution

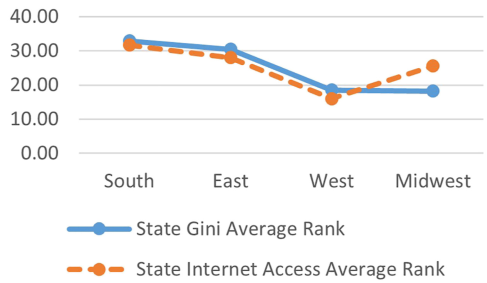

Figure 5.
Average Gini and Internet penetration ranks by region

to practice is for governments and industries to use Iceland and other similar countries as a model for policy, regulations, subsidies and investments. The Scandinavian blend of government investment and regulation, free market competition and infrastructure subsidies may show other countries (and states) how to improve infrastructure while also improving the well-being of its citizens. This has the potential to increase job opportunities for those in the middle and lower socioeconomic status. Also, ISPs only invest in infrastructure if they see a strong potential return on their investment, as they have a commitment to their organizational shareholders. This practice is understandable, but may limit broadband Internet in rural areas, countries with emerging economies, poor states, etc. It also may negatively affect job growth and opportunities for citizens. We urge governments to create subsidies to promote infrastructure development, such as South Dakota's federal grant funding, while also providing economic incentives to citizens. Federal subsidies should include more equal distribution, as currently 10% of federal infrastructure funding goes to California, with fewer federal subsidies in the South. Federal subsidies in infrastructure should also earmark a portion for funding for social programs. For example, 5% of all government infrastructure funding can go to support education initiatives, social welfare programs, Internet access and laptops for low-income families, etc.

Next, user adoption may be a key factor in improving inequality in relation to ICT infrastructure. DOI focuses on the five factors of relative advantage, compatibility, complexity, observability and trialability. If individuals do not see the advantage of a technology, are unable to use a technology due to lack of knowledge or owning a computer, they may not adopt productive ICT technologies. With Iceland's penetration at 99%, they have adopted the internet at a societal level, which has contributed to the decrease in income inequality, which in turn improves the well-being of individuals. The factors of affordability, business innovation, individual usage, and infrastructure have the potential to decrease income inequality. In the US, non-government organizations may provide support by developing training programs, refurbishing old computers for less fortunate populations and applying for federal funding to support these programs.

This study contributes to research by exploring the effects of Internet diffusion on income inequality. Most research on these relationships comes from sociology and economics, but IS can be an important discipline in these phenomena as well. Second, this research found the tenets of DOI regarding the relationship between technology diffusion and income inequality do not hold regarding Internet infrastructure and use. Diffusion of Internet infrastructure has a positive effect on income inequality at the country level, especially in emerging economies—as such, researchers can extend this research to understand the factors and antecedents that positively affect income inequality. Third, even though the US has high Internet diffusion, income inequality is extreme, which decreases the well-being of its citizens. Researchers can focus on the local and regional level such as state government policies and regulations, ISP investments, etc. Moreover, diffusion and inequality differ by region, so researchers can explore the underlying factors for each region in the US. Last, researchers can improve the quality of the data regarding Internet diffusion and inequality. As described in the data analysis, data for this study comes from multiple sources, and sources are no longer tracking the factors. Because this study explores the relationship between technology and inequality, and to individual well-being, researchers may be able to seek grant funding to improve the quality of data for understanding these phenomena.

Returning to the motivation for this study, Roger McNamee and his colleagues' observation holds true in California, as they experience incredible inequality despite having tremendous access to benefits of ICTs. Globally, this relationship is different. McNamee says, "With the proper regulations, technology can once again be a driver of economic growth, while also being a force for good." Biden acted on this call—albeit indirectly—by securing $401 m in loans and grants to support broadband infrastructure projects for individuals and businesses in eleven states (Reuters, 2022) which have lower broadband penetration. The development and implementation of broadband takes a long time, so we may not realize or understand these affects for a decade. We encourage researchers to also heed McNamee's call to expand on this study to learn more about the underlying factors of inequality, thus potentially increasing the well-being of both local and global citizens.

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