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Unequal resilience: The duration of electricity outages

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ABSTRACT

The resilience of social, biophysical, and technological systems is of increasing scholarly and practical import. Guided by scholarship on disaster resilience, environmental inequality, and urban service inequality, we advance the study of "unequal resilience" in a critical infrastructure – the electric grid. We analyze inequality in electricity outage duration at the census block group level using data from the U.S. Census, the U.S. Geological Survey, and a U.S. electrical utility's database of power outages from 2002 to 2004. Our intersectional approach identifies a factor variable of American Indian disadvantage as a correlate of average outage duration – suggesting possible support for an institutional bias hypothesis. However, spatial error regression models demonstrate that unequal resilience within our study area is most consistently explained by proximity to priority assets (i.e., hospitals), average downstream customers affected by outages, and environmental conditions (i.e., the seasonality of outages). These results are consistent with existing research on utilities' response to power outages, and more broadly with the bureaucratic decision rules perspective on service inequalities. We discuss the implications of our findings for future research and energy policy.

1. Introduction

Scholars, policymakers, and planners are paying increasing attention to the resilience of social, biophysical, and technological systems. The resilience of critical infrastructures is viewed as particularly important. Such infrastructures are "so vital that their incapacitation or destruction would have a debilitating impact on defense or economic security" (U.S. President's Commission on Critical Infrastructure Protection, 1997:B-1). Resilience as it pertains to critical infrastructures refers to "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions" (U.S. Department of Homeland Security, 2015). Thus, a key part of the resilience of critical infrastructures is the speed with which function is restored (Davoudi, 2012; Francis and Bekera, 2014; Holling, 1973, 1986, 1996; Maliszewski and Perrings, 2012; Tierney, 2014).

Our critical infrastructure of study is a portion of the electric power grid in the United States. The U.S. electricity delivery system is the largest machine ever created, representing more than $1 trillion (U.S.) in asset value. It includes more than 3,000,000 km of transmission lines, 950,000 MW of generating capability, and nearly 3500 utility organizations serving well over 100 million customers and 283 million people (Liscouski and Elliot, 2004). The electrical grid is a vast, complex infrastructure that is essential to human life in the United States. Substantial research investigates the causes of power outages and effective strategies for rapid restoration.

However, while policy makers, utilities, and researchers are concerned about the resilience of the electric grid, little attention has been paid to exactly *who* is affected by failures in resilience (e.g., Francis and Bekera, 2014; Maliszewski and Perrings, 2012). Because electricity is essential for life in contemporary society, lack of knowledge about disparities in provision is a problem. Given the monopoly status that utilities enjoy and the "just and reasonable" U.S. utility regulatory compact (McDermott, 2012; Oppenheim, 2016), utilities have an obligation to provide reliable electricity. If disadvantaged communities consistently experience longer electricity outages than their more advantaged neighbors, then utilities are arguably not meeting their mandate to serve the public interest (RAP, 2011). Further, such dynamics mean that utilities may be producing or exacerbating distributional energy injustices with potentially life-threatening consequences for disadvantaged communities (Bickerstaff et al., 2013; Browning et al., 2006; Ghanem et al., 2016; Halff et al., 2014; Heffron et al., 2015; Hernández, 2015; Jenkins et al., 2016; Klinenberg, 2002; Lin et al., 2011; Procupez, 2016; Reames, 2016; Sovacool and Dworkin, 2014; Sze, 2007; Walker and Day, 2012).

Existing research on the provision of a variety of services highlights the importance of two dynamics. On the one hand, socially marginalized people and places experience longer service disruptions and other adverse negative environmental consequences of institutional actions, suggesting potential institutional bias. This theme points to the

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existence of what we call "unequal resilience;" that is, the extent to which the return to system equilibrium is unevenly experienced throughout the system. On the other hand, bureaucratic rules of organizations shape the environmental and service experiences of communities, suggesting that factors other than institutional bias play a role in producing unequal outcomes. Given these insights, the present study seeks to answer two research questions. First, do socially disadvantaged neighborhoods experience greater disruption to their electricity supply than more advantaged neighborhoods? Second, to what extent are inequalities in electrical service disruption due to institutional bias or to other factors?

To answer our research questions, we analyze the relationship between block group-level population composition and average outage duration in our U.S. investor-owned utility service area from 2002 to 2004. Data are drawn from the U.S. Census, the U.S. Geological Survey, and the utility's database of electrical power outages. Guided by the literature on intersectional environmental inequality (e.g., Ard, 2015; Collins et al., 2011; Downey and Hawkins, 2008; Liévanos, 2015, 2017; Pulido, 1996), we identify a factor variable of American Indian disadvantage as a positive demographic correlate of average outage duration. This initial finding suggests possible support for an institutional bias hypothesis of unequal resilience. However, spatial error regression models demonstrate that unequal resilience within our study area is most consistently explained by proximity to priority assets (i.e., hospitals), the average number of downstream customers affected by outages, and environmental conditions (i.e., the seasonality of outages). Results support the bureaucratic decision rules perspective (Meier et al., 1991; Oakley and Logan, 2007) – showing that utilities prioritize essential community assets and engage in customer triage (Maliszewski and Perrings, 2012).

That is, we find that disadvantaged neighborhoods experience longer outage duration. This difference in duration is not due to bias, but rather to rational bureaucratic decision-making, which is reflected in faster service restoration for neighborhoods near qualitatively important priority assets and with the greatest number of downstream customers affected. Nonetheless, we argue that such utilitarian bureaucratic decision rules limit the recognition of systematically-patterned and unequal service disruptions and the development of corrective actions. We conclude by discussing some of the policy implications of this inequality, especially for expanding the U.S. utility regulatory compact and the Low Income Home Energy Assistance Program, and we outline directions for future research on unequal resilience and energy justice.

2. Background and hypotheses

We begin by exploring insights from existing literature on dynamics that contribute to inequality, and the implications of this work in the context of the electric grid. We then examine work that seeks to disentangle inequalities due to institutional bias from those that are unintended. Our study does not provide a comprehensive analysis of all the factors that cause electrical outages and their duration. Rather, we focus on key factors relevant for testing our theoretical argument and apply our theory to a specific empirical case – a U.S. investor-owned utility district with particular forms of socioeconomic and racial disadvantage.

2.1. Neighborhood disadvantage and institutional bias

Research shows that socially marginalized people and places generally do not experience their material and social environment the same way as other segments of the population. Some environmental inequality researchers attribute these differences to biased institutions. For example, Ard (2015) uses an institutional bias perspective to explore enduring racial inequalities across the U.S. She highlights the contributions of policy-salient geographic areas to unequal environmental exposures. Such areas include, for example, U.S. Environmental Protection Agency regional divisions that oversee environmental enforcement activities, counties that carry out planning activities, and central city districts that have a legacy of segregated spaces and concentrated industrial activity (see also Sze, 2007).

Similarly, urban service inequality researchers have tested an "underclass hypothesis" (Lineberry, 1977). This perspective suggests that the concentration of socioeconomically disadvantaged, nonwhite, and/or politically marginalized residents in a neighborhood is associated with inferior services. This outcome is attributed to institutions favoring elite neighborhoods or overtly discriminating against disadvantaged neighborhoods (Lineberry, 1977; Wells and Thill, 2012). Researchers have found varying levels of support for this hypothesis in the distribution of police and fire (Boyle and Jacobs, 1982; Cingranelli, 1981), education (Feiock, 1986), parks (Talen, 1997), and transportation (Wells and Thill, 2012) services in some U.S. urban areas.

Thus, a theme across the literature is that particular segments of the population may experience biased treatment by institutions in a manner that varies depending on geography, history, and institutional context. It is therefore usually up to the researcher to empirically specify the disadvantaged population that is relevant to their study area. For example, Wells and Thill's (2012) study of bus service access in four southern U.S. cities expanded Lineberry's (1977) notion of the underclass to transportation-dependent riders like students and the elderly in addition to nonwhites and low-income individuals. Liévanos (2017) deployed an intersectional approach that specified the multiple domains of disadvantage – race, ethnicity, poverty, limited educational attainment, and English-speaking ability – that were correlated with vulnerability of exposure to toxic surface waters in California's Bay-Delta region (see also, Collins et al., 2011; Downey and Hawkins, 2008; Liévanos, 2015; Pulido, 1996).

We focus on neighborhood concentrations of socioeconomically disadvantaged American Indians.[1] American Indians were the most numerous minority group in our study area and time period, constituting 2.11% of the population in 2000. They have a history of subjugation reflected in centuries of forced assimilation, relocation, and isolation (Steinman, 2012). They have also experienced exclusionary environmental policy and disproportionate exposure to environmental hazards, often for the purposes of U.S. national security and energy resource development (Hooks and Smith, 2004; Vickery and Hunter, 2016). Research indicates that the disadvantaged social and historical position of American Indians may compromise their contemporary access to secure and stable energy resources (Brookshire and Kaza, 2013). Despite the recent growth in Native gaming establishments in the U.S., marginalized segments of the American Indian population (e.g., those with low to moderate income and tenuous employment) experience particularly enduring disadvantages (Davis et al., 2016). Such marginalized households are prominent in the urbanized, non-tribal land settings in our study area. Accordingly, we use American Indian disadvantage to test an institutional bias hypothesis of electrical outage duration:

Hypothesis 1. The *institutional bias hypothesis* states that neighborhood levels of American Indian disadvantage will be positively associated with neighborhood levels of average outage duration.

Because communities differ in population settlement patterns and racial histories (Pulido, 2006), hypotheses regarding a particular racial-ethnic group in one region of the world do not necessarily apply to that same group in other areas. We limit our focus to the disadvantaged

[1] We follow convention and use "American Indians" to refer to Native and indigenous populations in our study area because of the prevalent use of the term within previous related scholarship (e.g., Brookshire and Kaza, 2013; Davis et al., 2016), American Indian communities, and our U.S. Census data which technically refers to American Indian and Alaska Natives.