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Measuring externalities of energy efficiency investments using subjective well-being data: The case of LED streetlights

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ABSTRACT

Outdoor streetlights are among the highest recurring energy-related expenses faced by municipalities. As a cost-savings measure, many cities have recently made large investments in energy efficient light emitting diode (LED) streetlights. Most LED streetlights produce a different wavelength of light that is often brighter than that produced by existing lights, which has led to high-profile debates on their impacts to the environment, human health, crime, and transportation safety. However, there is a lack of credible empirical evidence on the direction and magnitude of LED streetlight externalities, including their impacts to subjective well-being. To address this knowledge gap, we investigate local externalities of investments in LED streetlights across the 100 largest US counties by population using subjective well-being data from the US CDC Behavioral Risk Factor Surveillance System over 2005–2010. Difference-in-differences results suggest that LED retrofits generate significant positive well-being impacts, varying by respondent demographic characteristics and the number of streetlights replaced. On average, installing LED streetlights generates an externality equivalent to a $477 (6.9%) increase in per capita monthly household income.

1. Introduction

Since the commercialization of the incandescent light bulb in the late 19th century, electric lighting has fundamentally changed how modern economies operate. The outdoor electric streetlight, in particular, revolutionized nighttime environments by illuminating previously darkened roads, walking paths, bridges, outdoor spaces, and highways, and has led to improvements in nighttime safety (Boomsma and Steg, 2014) and reducing transportation accidents (Wanvik, 2009).

Streetlighting technology advanced considerably in the 20th century, driven first by brightness concerns and later by efforts to improve energy efficiency. The US Department of Energy (DOE) estimates that there are 26.5 million streetlights in the US with annual energy consumption totaling $2 billion (US DOE, 2013). Inclusive of operation and maintenance costs, approximately $4–6 billion per year is spent on streetlights (US DOE, 2013). Streetlights are often the highest recurring monthly energy-related expense faced by municipalities. For example, Los Angeles spent $15 million on their streetlights in 2009, while in 2010 Boston spent $8 million (US DOE, 2013; City of Los Angeles, 2009).

Efforts to bolster the energy efficiency of streetlights took a prodigious leap forward with the commercialization in the late-1990s and early-2000s of light emitting diode (LED) streetlights, which use ~50–65% less energy than traditional gas-discharge lamps, have improved lifespans, and lower maintenance costs.[1] Not surprisingly, hundreds of cities across the

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[1] Commonly used gas-discharge streetlights are high-pressure sodium, low-pressure sodium, mercury vapor, and metal halide. Light is generated by sending an electrical current through an ionized gas.

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US, including Los Angeles, New York, Boston, and San Francisco have retrofitted their existing gas-discharge streetlights with LEDs. The Los Angeles program is the largest retrofit project completed to-date, where over 141,000 streetlights were replaced with LEDs, saving the city an estimated $10 million per year in reduced energy and maintenance costs (City of Los Angeles, 2013).

LED streetlight retrofits have been referred to as “no-brainer” and “win-win” decisions, characterized, similar to other investments in energy efficiency, as an example of a situation where there are dollar bills on the ground just waiting to be picked up (Seidel, 2016, April 17; City of Los Angeles, 2013). On a pure energy efficiency basis, there is credible evidence that LED retrofits do indeed generate positive returns on investment after only a few years (e.g., Beccali et al., 2015). However, commonly used return on investment calculations routinely ignore potential spillover effects or externalities of LED streetlights on society (IES, 2014). Depending on the direction and magnitude of the local externalities, the returns of LED streetlight retrofits may differ, perhaps considerably, from pure accounting estimates.

LED streetlight externalities may take several forms. Compared to existing gas-discharge streetlights, LEDs often produce brighter, more broad-spectrum light that is perceived as being closer to daylight (Jin et al., 2015). This characteristic of LEDs has been shown to improve nighttime visibility, color rendition, and light uniformity in urban environments, which may help reduce vehicular and pedestrian accidents (Gibbons and Clanton, 2012). LED streetlights may also contribute to lower crime rates and increased perceptions of safety and well-being at night (Peña-García et al., 2015). For example, the City of Los Angeles has partially attributed reductions in vehicle thefts, burglaries, and vandalism to improved visibility after their LED retrofit (Gerdes, 2013, January 25). However, the peer-reviewed literature on LEDs and crime is mixed (Steinbach et al., 2015). But, experts on lighting and crime acknowledge that installing LED streetlights may lead to people taking more pride and ownership of their communities, which can aid in community policing (Chaban, 2016, July 11).

Public health and ecological externalities may also exist. In 2016, the American Medical Association (AMA) issued guidance on LED streetlights, suggesting that the types of lights commonly being used may be harmful to human health (AMA, 2016). While any prolonged exposure to artificial light at night can be harmful to health, blue-white light emitted by LEDs, in particular, is more harmful than light from existing gas-discharge fixtures (Haim and Portnov, 2013). In particular, exposure to blue-white light from LEDs is associated with increased rates of breast and prostate cancers, obesity, insomnia, poor sleep quality, and stress (for reviews see AMA, 2016; Gaston et al., 2014; Haim and Portnov, 2013). Hence, switching from gas-discharge lamps to LEDs may exacerbate these public health outcomes. Moreover, LED streetlights also have known ecological impacts on biodiversity, predation, nocturnal activity, and circadian rhythms (Gaston et al., 2013; Stone et al., 2012).

Externalities associated with LED streetlights have generated significant public controversy, with some suggesting that LED impacts on public health and the environment are probably minimal and are likely no different than the effects of current lights (e.g., US DOE, 2016). Conversely, others maintain that commonly used blue-white light producing LEDs should not be used in streetlighting applications because of their significant negative externalities (e.g., AMA, 2016).[2] In an attempt to mitigate some of the public health and ecological concerns, a middle-ground has formed around using LED streetlights that produce little or no blue-white light and instead have wavelengths similar to those found in existing gas-discharge lamps (e.g., “cool” white light). Though at present very few cities are using “cool” white LEDs and researchers at the University of Connecticut have also questioned their health and environmental impacts (Stevens, 2016, June 17).

Clearly, this contentious issue is far from settled and it is not our intention to jump into ongoing debates or to try and defend one side over another. Rather, this paper adopts a neutral position from the outset and instead seeks to provide a credible empirical investigation into the local well-being impacts of LED streetlights, quantifying, where possible, the magnitude of any observed externalities (whether positive, negative, or both). We believe that our analysis will contribute much needed empirical evidence that is presently missing from the largely anecdotal and qualitative debates occurring on the pros and cons of investments in streetlights. While there are many claims that LED streetlights are “good” or “bad” for the public, in actuality the post-retrofit well-being effects of these lights are largely unknown, especially across US urban areas and over time. This is troubling because it means that large investments are being made in energy efficient streetlights without a clear understanding of their holistic impacts on society.

Specifically, this paper addresses the following issues: (i) What are the *ex-post* local life satisfaction effects of LED streetlight retrofits? (ii) Do the observed effects depend on the number of lights replaced? (iii) How do the life satisfaction effects vary over time? (iv) Are there heterogeneous impacts of LED conversion programs on diverse subsets of the urban population?

To investigate these questions, we use 2005–2010 cross-sectional data on 312,525 US adults’ subjective life satisfaction from the US CDC Behavioral Risk Factor Surveillance System (BRFSS) and data on LED streetlight retrofit projects for the 100 largest counties in the US by population. Several large LED retrofits occurred across a diverse set of US counties over our study period, providing us with a rich source of variation in streetlight coverage. A difference-in-differences model is used to compare individuals in counties that retrofitted their streetlights to LEDs with similar individuals in counties contemporaneously not using LEDs. Several different difference-in-differences specifications are used to address our research questions.

[2] Print and television news outlets have also picked up on the LED streetlight controversy, with high-profile articles appearing in outlets such as *The New York Times* (Chaban, 2016, July 11), *CNN* (Stevens, 2016, July 21), and *The Washington Post* (Ollove, 2016, September 25), including a segment on the nationally-broadcast NBC TODAY show on October 4, 2016.