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Effects of construction activities on residential electricity consumption: Evidence from Singapore's public housing estates☆,☆☆

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ABSTRACT

This study aims to empirically test the effects of negative environmental externalities (i.e. noise pollution) due to construction activities within half to one kilometer (km) radius and how households react to such externalities by increasing the use of air-conditioners to mitigate noise from the construction work. We use a unique dataset of electricity consumption by public housing residents in Singapore measured at the building level and merge it with the dataset of construction sites for the periods from 2009 to 2011. Using a difference-in-differences approach, we find that electricity consumption by the households living close to the construction sites increases by 6% compared to the households who are not affected by noises from construction sites during the construction periods, after controlling for building and month of the year fixed effects. The results remain robust after controlling for spatial autocorrelated lag and error terms. The economic cost of the construction externalities for each household amounts to approximately S$98 per annum. We also find that the increases in electricity consumption of the affected households were persistent, and the electricity consumption of the affected households did not revert to the pre-construction levels, after the removal of the negative externality.

1. Introduction

Rising energy consumption is a global concern. Household electricity consumption is growing at an alarming pace in tandem with rapid urbanization processes, especially in emerging economies. Energy (electricity) consumption is one of the key factor inputs in the "production" of dwelling comfort (indoor air temperature) for households (Quigley, 1984; Quigley and Rubinsfeld, 1989). Households use energy (electricity) ("purchased comfort") to substitute deficiencies caused by poor housing designs (such as rooms, vintage, etc.) and undesirable climatic conditions to attain expected interior comfort of dwelling ("produced comfort"). Households increase electricity consumption to mitigate effects of exogenous shocks that could reduce their expected comfort level, such as noise and dust from nearby construction sites.

When facing construction noise and pollution (externalities), households either adopt a passive approach by adjusting their lifestyle while hoping that the noise could be kept within an acceptable level via government regulations[1]; or take a pro-active action to mitigate the externalities. Many affected households may "*self-protect*" against construction noise by shutting off windows and doors and air-conditioning indoor environment. As there is no contractual relationships between contractors/builders and households affected by construction noise, it is difficult to verify if the "self-protection" actions of households could induce moral hazard in contractors/builders (Ehrlich and Becker, 1972).[2] While it is not within the scope of this

☆ We would like to thank the National Environmental Agency (NEA) for sharing the electricity consumption data used in this study. The technical assistance of Mi Diao on the spatial panel data model is also greatly appreciated.
☆☆ Data appendix: The electricity consumption data are provided exclusively and restrictively for this study by the National Environmental Agency (NEA) of Singapore. The data will not be made available in public domain due to the non-disclosure agreements imposed on the dataset. Replication of empirical results on site at National University of Singapore could be made upon request.

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[1] In Singapore, the government enacts the "Environmental Protection and Management (Control of Noise at Construction Sites) Regulations" (Chapter 94 A Section 77) to protect excess noise/dust generated from construction sites. Under the act, builders of residential projects are required to abide by the maximum permissible noise level of 75 decibels (an equivalent continuous noise level over a period of 12 h between 7 am-7 pm).

[2] Ehrlich and Becker (1972) develop a theoretical framework to explain moral hazard in the demand for insurance. In their insurance demand model, self-insurance and self-protection are considered as alternative systems to market insurance. While self-insurance is intended to minimize the size of a loss, self-protection is meant to reduce the probability of a loss. They show that market insurance leads to the moral hazard behaviour of insurers.

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study to test the moral hazard behavior of contractors/builders, this study instead aims to empirically test how electricity consumption behavior of households could be influenced by the self-initiated protection in mitigating local externalities associated with noise and dust from adjacent construction sites.

Traditionally, there are two approaches by which negative environmental externalities are valued. The first approach uses stated preference methods (e.g., contingent valuation) to estimate subjective social costs associated with environmental disturbances. The second approach uses market transaction data to objectively estimate costs of negative externalities. Our quasi-experiment uses Singapore's electricity consumption data at the building block level to test behavioral responses of households to negative externalities caused by construction activities on adjacent sites. The advantages of using Singapore's electricity consumption data are two-fold. First, Singapore being located in the tropical climate zone has a relatively constant temperature with high humidity. Typical households use on average 30% of electricity in air-conditioners to provide cooling comfort for internal space.[3] Second, Singapore is a densely-built urbanized city, where new construction activities are a common part of the urban fabric. Construction noise could induce "*self-protection*" responses of households to minimize dis-utilities in dwelling by using air-conditioners to cool indoor space. Therefore, externalities caused by nearby construction activities could significantly increase electricity costs (externality costs) incurred by households.

As "comfort" level is not observable in reality, this study uses a distance measure to proxy the intensity of construction noise externalities in our identification strategy. We use two distance dummies to identify housing estates that are located within 0.5 km (km) and 1.0 km (by shortest distance) from construction sites, respectively, depending on the scales of construction projects (by square meters gross floor areas) as proxies for the effects of environmental externalities (construction noise). By the distance to the nearby construction sites, we sort the sample buildings into a treatment group consisting of building blocks located within 0.5 km of construction sites with total gross floor areas (gfa) of less 5000 square meters (sqm), and/or 1.0 km of large construction sites with more than 5000 sqm in gfa. Other buildings that are located outside the "treatment" boundary are sorted into a control group. The construction sites data are obtained from the Building Construction Authority (BCA). We then empirically test for variations in block-level electricity bills for the two groups before and during the construction period.

Using a set of electricity bill data for public housing blocks in Singapore for the periods from 2009 to 2011, our results show that the "treatment" housing blocks consume significantly more electricity in the same months after controlling for heterogeneity in housing attributes and location fixed effects. The negative externality caused by construction noise is estimated at about 6.0%, based on differences in electricity consumption between the treatment samples and the control samples. In term of average monthly electricity consumption, the 6% differences is translated into an equivalent of 30.15 kWh per household[4]; and compared with the monthly electricity consumption of 184 kWh, 273 kWh and 373 kWh for 2-room, 3-room and 4-room public housing flats,[5] respectively, the construction noise externalities cause electricity consumption to increase by between 8.1% and 16.4% per households. If the electricity tariff of 0.27 cents as in 2009 is used as the reference, the construction noise externalities are translated into approximately S$9770 per block per annum in the economic term.[6] In our total sample of 4682 housing blocks, 1617 blocks were identified as the treatment blocks; and the total economic costs are estimated at around S$15 million in an aggregate term for households living in these blocks.

The results imply that households use self-protection measures, such as air-conditioning indoor environment to mitigate externalities associated with construction noise and pollution from nearby construction sites. This action causes the electricity bills of housing units in treatment blocks to increase relative to other far-away blocks, *ceteris paribus*. We find that household electricity consumption behaviors did not revert to the original pattern, after construction activities have been completed. Increases in electricity consumption are persistent; and we find no evidence of rebound effects as in Reiss and White (2005). The habit persistence behavior of household is one possible reason for not observing the rebound effects (persistence in electricity consumption behavior) in the treatment households, who may find it hard to switch back to non-air-conditioned indoor environment after the construction works have been completed.

This paper makes three contributions to the literature on residential energy consumption. First, we find evidence to suggest that households shut off windows and doors, and air-condition their rooms as a "self-protection" mechanism to negate "dis-utilities" caused by construction externalities. These households are unlikely to endure passively with diminishing levels of dwelling comfort caused by construction noise. Second, we estimate the economic impact of negative externalities caused by construction activities on public housing estate using energy (electricity) consumption data. Households incurred marginal private costs in electricity consumptions when making short-term responses to negative externalities generated from adjacent construction activities. Third, we find no significant rebound effects in household electricity consumption behavior at the end of the construction activities.

The remainder of the paper is organized as follows: Section 2 reviews past studies of residential energy (electricity) consumption behavior. Section 3 provides background on residential electricity consumption and housing construction activities in Singapore. Section 4 describes data sources and empirical methodologies. Section 5 analyzes empirical results and draws necessary inference on households' adjustment of dwelling comfort through increases in electricity consumption. Section 6 concludes by highlighting limitations of the study.

2. Literature review

There are two strands of literature on residential energy consumption. The first strand of literature models energy consumption as a factor input into the production of comfort in dwelling ("purchased comfort"). Quigley (1984) and Quigley and Rubinsfeld (1989) explicitly separate housing attributes that provide direct satisfaction to households, such as vintage, room arrangement and size, from attributes that use energy (electricity and gas) as inputs to the production of thermal comfort ("produced comfort"), such as furnaces and air-conditioners. Quigley (1984) tests the impact of energy price changes on demand for housing services and input factors using a sample of newly constructed dwelling, and finds that high energy prices induce "conservationism" in household energy consumption. Quigley and Rubinsfeld (1989) show that high energy prices have a positive impact on housing prices and households choose to substitute housing vintage (attributes) for production input in housing services (energy consumption). The elasticity of substitution between "purchased comfort" (energy consumption) and

3 An energy report published by the Energy Efficient Program Office (E^2PO), a Singapore's government agency led by the National Environment Agency (NEA) showed that the household sector consumes one-fifth of the total electricity in Singapore, and 30% of the household electricity was accounted for in the use of air-conditioners.

4 We do not have household level data to directly compute externality costs for each household. We make an assumption that a typical public housing (HDB) block consists of approximately 100 housing units. The numbers of households may differ by block layout size, and number of floor in each block.

5 The electricity consumption data are based on the statistics reported as in December 2014by Singapore Power Limited, the main utility firm that distributes electricity in Singapore.

6 Based on the 100 households per block assumption, the per household cost of externality works out to be approximately S$ 97 for a household living near a construction site and subject to noise and dust from the site for a period of 1 year.