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Carbon emissions from the commercial building sector: The role of climate, quality, and incentives☆

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ABSTRACT

Commercial buildings play a major role in determining U.S. greenhouse gas emissions, yet surprisingly little is known about the environmental performance of different buildings at a point in time or how the same buildings perform over time. By exploiting a unique panel of commercial buildings from a major electric utility, we study the association between a building's electricity consumption and the physical attributes of buildings, lease incentive terms, indicators of human capital, and climatic conditions. We find that buildings that are newer and of higher quality consume more electricity, contrasting evidence for the residential sector. However, using our panel data set, we document that newer buildings are most resilient when exposed to hotter weather. Those buildings that have a building manager on-site and whose tenants face a positive marginal cost for electricity also demonstrate a better environmental performance.

1. Introduction

Economic research investigating urban greenhouse gas production has mainly focused on the transportation sector's consumption of gasoline, the residential sector's energy consumption, and the power generation sector's carbon emissions (Glaeser and Kahn, 2010; Ito, 2014; Kotchen and Mansur, in press). But in the service economy, most work activity takes place in commercial buildings and a significant amount of shopping activity occurs in the commercial sector's structures. The commercial sector is thus a major user of natural resources — its share of total U.S. energy consumption was 18% in 2013.[1]

Electricity is the most important source of energy used in the commercial building stock, and the sector's share of electricity consumption has been rising over time.[2] Given that 40% of U.S. electricity consumption is generated using coal and 29% using natural gas, there is a significant unpriced greenhouse gas externality associated with electricity consumption.[3]

Despite the importance of the commercial property sector as a consumer of electricity, and thus as a major producer of urban carbon emissions, we know very little about the environmental performance of its buildings, and the effectiveness of energy policies addressing the externalities from commercial buildings. Lack of access to good data has limited our knowledge of the core facts — for instance, the most comprehensive source of data, the Department of Energy's Commercial

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[1] See http://www.eia.gov/totalenergy/data/browser/xls.cfm?tbl=T02.01&freq=m.

[2] According to the Energy Information Agency (EIA), in 2013 about 79% of the total energy consumption in commercial buildings was from electricity (18% was from natural gas). Forty years ago, electricity represented 54% of the total energy consumption in the commercial stock. See http://www.eia.gov/totalenergy/data/browser/xls.cfm?tbl=T02.01&freq=m.

[3] See http://www.eia.gov/totalenergy/data/browser/xls.cfm?tbl=T07.02B&freq=m.

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Buildings Energy Consumption Survey (CBECS), was last conducted in 2003; this nationally representative data set offers cross-sectional information on the energy consumption of just 5,000 buildings. There is a small body of research about commercial building energy consumption, mostly conducted by engineers, exploring either aggregate consumption data at the state or national level (Horowitz, 2004), or analyzing small samples of buildings (see Hirst and Jackson, 1977, for an early analysis; see also Ham et al., 1997).[4]

In this paper, we exploit access to a unique dataset to study the electricity consumption of a large sample of commercial buildings located in a county in the Western U.S. Using our cross-sectional data, we investigate the determinants of commercial building energy consumption, exploring the association between building quality and lease incentive terms, and building electricity consumption. Our results show that the higher quality, newer vintages of commercial buildings actually consume *more* electricity than older buildings. This finding contrasts evidence on energy consumption trends for residential structures (Costa and Kahn, 2011). In comparing the environmental performance of newer and older buildings, we discuss relevant regulatory building codes.

Second, we examine the split incentive problem between the commercial building's tenant and its landlord. If incentives determine electricity consumption, then the structure of contracts has direct implications for the sector's greenhouse gas production. Lease contracts can be structured as all-inclusive, "full gross" contracts, or excluding utility cost ("triple net") contracts, providing a standard principal–agent problem (Sappington, 1991) where the occupant chooses how much effort to exert on saving resources. The "full gross" contract provides the weakest incentives for a tenant to conserve on electricity consumption but incentivizes the building owner to make investments in energy efficiency. In contrast, the "triple net" lease incentivizes the tenant to economize on electricity (and thus greenhouse gas production) but provides weaker incentives for the building owner. We document that tenants whose utilities are bundled into the rent consume more electricity than observationally identical tenants who pay their own bills — similar to findings for residential housing (Levinson and Niemann, 2004). While most studies have pointed to the disincentives for landlords to make optimal investments in energy efficient appliances (Davis, 2010), we focus on the incentives for tenants to conserve on energy consumption, as provided by the lease framework.

By exploiting our data's monthly panel structure, we then test what types of buildings are most resilient when exposed to hotter weather. There is a growing consensus that carbon emissions will alter the earth's climate, most notably by causing temperatures and weather variability to increase. This has significant and direct implications for the average energy consumption in buildings (Dêschenes and Greenstone, 2011), but it may also affect the maximum, or peak demand for electricity from buildings (Chong, 2012). Our results highlight what types of commercial real estate increase their electricity consumption the most during hot summers. Such estimates are relevant for predicting grid resilience (a local public good) in the face of increased summer temperature.

Contrasting results for average consumption levels, we document that newer buildings increase their electricity consumption less on hotter days as compared to the average building — they are more resilient to temperature shocks. Using the data on the leasing arrangements of space within buildings, we document that tenants who face a zero marginal cost of energy consume relatively more electricity on hotter days. This finding highlights the important role that occupant behavior plays in determining a building's electricity consumption dynamics. On hotter days, there will be greater demand for air-conditioning and this demand will be even higher in buildings where tenants face a zero marginal cost for consumption because they have a full service lease.

We acknowledge that our findings are not based on a randomized experiment. In an ideal randomized trial, heterogeneous tenants would be randomly assigned to different buildings under randomized lease terms and then be exposed to randomized climate conditions. We would then study the electricity consumption of different commercial buildings as a function of the building's attributes, the tenants' attributes, the lease contract's terms and the outdoor climate conditions. In such a case OLS estimates of the electricity consumption would yield causal effects. In reality, there is a market for commercial real estate and a hedonic pricing gradient emerges as heterogeneous potential tenants choose their optimal location. In Section 2 of the paper, we explicitly discuss this assignment problem and the assumptions that must hold for our OLS estimates to not suffer from bias due to omitted variables and self-selection issues.

Our paper's focus on commercial buildings makes it considerably different from the growing literature on the environmental performance of the building stock, which is primarily focused on the residential sector. One hypothesis in the residential literature is that consumers underinvest in energy efficiency. This perceived market failure has been addressed through second-best responses such as standards and subsidies (Allcott et al., 2014). For example, Jacobsen and Kotchen (2013) document small but significant impacts of changes in building codes on the efficiency of residential dwellings in Florida, whereas Chong (2012) investigates changes in residential energy consumption in response to temperature shocks, finding that new buildings use more energy in hot weather. Allcott (2011) studies occupant behavior, documenting that residential customers reduce their electricity consumption when receiving peer comparisons that show how their consumption compares relative to their geographic neighbors.

The remainder of this paper is organized as follows: Section 2 describes the empirical framework and the econometric models. Section 3 discusses the data, which represent a unique combination of building-level electricity consumption with detailed information on the characteristics and occupants of those buildings. Sections 4 and 5 provide the main results, conclusions, and policy implications of the findings.

2. Empirical framework

The commercial real estate sector is a major consumer of electricity. This electricity consumption raises U.S. greenhouse gas emissions and exacerbates the risk of climate change. Thus, privately optimal choices for consumers impose social costs. We use our unique data to explore the major sources of this externality.

To begin to study this issue, we first document overall time trends. As Fig. 1A illustrates, the fraction of electricity consumed in residential and commercial (i.e., office, retail and industrial) buildings in the U.S. has increased from a total of about 52% in 1960 (29% residential and 23% commercial) to about 75% in 2010. For comparison, Fig. 1B shows that in California the fraction of electricity consumed in buildings has increased from about 65% to 81% during the same period. The commercial sector currently consumes about a third more than the residential sector in California.

At a point in time, a commercial building's electricity consumption depends on the building's physical attributes, the set of tenants who locate in the building, the incentives these tenants face for purchasing and operating energy intensive durables, and the outdoor climate conditions. The relevant physical attributes include the building's square footage, vintage and architecture. Once the building is in operation, its electricity consumption will be a function of core building energy

[4] Recently, several working papers on commercial building energy consumption have emerged. Qiu (in press) analyzes the impact of energy efficiency technologies on steady state energy consumption, while Papineau (2013) investigates the capitalization of efficiency gains following the adoption of more stringent buildings codes, and the heterogeneity of the effects across leasing arrangements.