THE MARGINAL GENERATION AND EMISSIONS IMPACTS OF HYDROPOWER: EVIDENCE FROM THE COLORADO RIVER STORAGE PROJECT

Jesse Kaczmarski, University of Alaska Fairbanks, Alaska Center for Energy and Power, (505) 313-5525, jikaczmarski@alaska.edu
Benjamin Jones, University of New Mexico, Department of Economics, N/A, bajones@unm.edu

Section 1: Overview

As electric grids continue to modernize through infrastructure improvements and increased intermittent capacity, hydropower has an important role as a source of low-emission electricity that supplies both baseload and peaking power. In many areas of the world, hydropower production is under threat of becoming less flexible due to regulatory constraints, ongoing drought, and changing weather patterns associated with climate change. Hydropower has historically been known to offset dirtier and more expensive fossil fuels, but the scope and magnitude of these offsets remain understudied. To-date, there has been no work that directly examines the generation, emissions, and air pollution effects of replacing fossil fuel power generation with hydropower. In this study, we provide the first evidence of forecastable hydropower generation and pollutant (CO_2, SO_2, and NO_X) offsets and ambient ozone reductions at the hourly level for a public non-profit power wholesaler.

Section 2: Empirical Approach

For our case study, we obtain hourly energy dispatch data from the Platte River Power Authority (PRPA), located in Colorado, USA, from 2016-2020. We also collect stack-level emissions data and ambient ground-level ozone data from the Environmental Protection Agency (EPA) for this study period. This data is paired with a high-dimensional fixed effects model similar to those presented by Novan (2015), Cullen (2013), and Castro (2019). The objective is to measure how hydropower, wind, and solar generation offset fossil fuel generation. We extend this analysis to measure how the same renewable production results in reductions to stack-level emissions and ambient ozone levels across the service region. Emprical specifications are withheld from this abstract for brevity. Finally, we input our findings of ground-level ozone reductions into health incidence functions to estimate the avoided health externalities had hydropower not been available. These four research outputs provide us with an understanding of how forecastable hydropower supply in the west reduces dependence on fossil fuels, reduces power plant emissions and ground-level ozone levels, and improves the health outcomes for local residents.

Section 3: General Results

We find the marginal effect of an additional unit (MWh) of hydropower is a reduction of all fossil fuel generation (natural gas and coal in this case) by 0.21 MWh. We also quantify the marginal effects of wind and solar generation. We then estimate the marginal effect of an additional unit of hydropower on levels of CO_2, SO_2, and NO_X from the study region's main generating facility, finding that hydropower is associated with offsets of 0.26 short tons, 0.18 pounds, and 0.28 pounds respectively. Finally, we use ambient ozone levels from monitoring stations in the study region and find that when accounting for dispersion, the marginal effect of an additional unit of hydropower is a reduction of ambient ozone levels by 0.0010 parts per million. we then approximate the spatial impacts of these findings on health outcomes using concentration response and health impact functions derived from the epidemiology literature. We find that hydropower supply avoids significant emergency room visits and hospital admissions for respiratory conditions, athsma exacerbation cases, and all-cause mortality.

Section 4: Conclusions

Our results shed light on an elusive topic, which is the quantification of hydropower's effect on the generator's optimization decision. Especially given the complex nature of the contractual and regulatory system in areas such as the Western US, isolating the effect of hydropower supply can prove difficult without a direct case study. This work serves as the first attempt to quantify generation, emission, and ozone offsets for use by stakeholders, policy makers, regulators, and industry professionals. We highlight the importance of these hydropower contracts on supplying power to its customers since it counts as renewable or low-emission on the buyer's energy mix. Engaging in contractual hydropower purchases from WAPA has the benefit of being low-cost but is hindered by contractual lower and upper bounds. Our hypothesis is that given an endless supply of hydropower, absent adverse environmental effects, utilities and other customers would consume far more hydropower, but fossil fuels are not likely to be removed entirely from the energy mix any time soon. Customers will still need to be able to react to non-forecasted demand which at present is met with power purchases or natural gas generation.

Given ongoing efforts to decarbonize the electric grid, we will likely continue to see the introduction of intermittent resources accompanied with regulatory frameworks demanding such (Ambec and Crampes, 2019; Sovacool, 2009). Hydropower can serve as an on-demand response to intermittent generation (Castro, 2019; Chang et al., 2013), and has the added benefit of already being installed, as opposed to capacity additive technologies. Unfortunately, due to our changing climate, it is getting more difficult for hydropower generation in areas under severe drought warnings, such as that of the Colorado River Storage Project and the Loveland Area Project. Reduction in hydropower capability is currently mitigated by optimizing flows throughout the river system as well as purchasing power from the spot market, but the latter may result in increased emissions in other areas if some portion of that power is generated with fossil fuels. This concept of emissions offshoring is a topic for future research. Regardless, external and internal threats to hydropower production, particularly in the Western US, will likely result in short-term increases in fossil fuel generation and thus ambient ozone and negative health impacts.

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