***Municipal Building Codes and the Adoption of Solar Photovoltaics***

Stefano Carattini, Georgia State University, scarattini@gsu.edu

Béla Figge, Georgia State University, bfigge1@gsu.edu

Alexander Gordan, Georgia State University, agordan1@gsu.edu

Andreas Löschel, University of Münster, loeschel@uni-muenster.de

## Overview

Climate change is one of the most pressing issues of this century. Tackling climate change implies transitioning as fast as possible to renewable sources of energy. Many countries have ambitious emissions reductions goals, Nationally Determined Contributions under the Paris Agreement, which are often translated into renewable energy goals. The share of renewable electricity has been increasing substantially across the globe, yet most countries are relatively far from reaching their goals. The widespread use of subsidies to renewable energy has contributed to a decrease in the price of solar installations, exceeding expectations (Creutzig et al., 2017; REN21, 2018). As solar energy reaches grid parity in many countries, governments are phasing out their subsidy schemes to promote the installation of solar photovoltaics (PV). This new era comes with new challenges for academics and policymakers. Assessing the role of non-price obstacles to the adoption of solar PV represents, arguably, the new frontier in research and policymaking.

In this paper, we leverage the context of Germany, the country in the world with the highest penetration of solar energy and the most mature market for solar PV, to assess the role of building codes in either supporting or preventing the adoption of solar PV. We combine geolocalized data on about 2,000,000 solar installations with a unique survey on municipalities’ current and past building codes affecting the adoption of solar PV and identify trade-offs between policies aimed at defining the aesthetics of German towns and the adoption of solar PV. Some of those trade- offs, however, may be overcome by technological advances in the market for solar PV, which have improved the aesthetics of solar installations, thus making some of the policies that we analyze potentially obsolete. Germany is particularly well suited to this inquiry because the country has a decentralized administrative structure, which gives municipalities substantial leeway beyond the federal- and state building codes. A significant share of German municipalities has implemented building codes that explicitly or implicitly regulate the installation of solar panels on buildings. To date, no comprehensive registry of municipal solar policies exists. A major contribution of our study is to create such a registry based on survey responses from municipal officials. In this survey, delivered to all municipalities in Germany, we ask for information about how the local building code treats the installation of solar panels. Regulations of solar installations include explicit bans in certain areas or the entirety of the municipality. Some municipalities have more subtle provisions, for example, such that solar installations cannot be visible from the street. Other municipalities have policies in place that promote solar photovoltaics. We obtained information on when municipal policies became effective or ceased to exist, if applicable, as well as on past policies. We match this information to federal data of mandatory reporting on the location and technical specification of solar panels connected to the electric grid and municipal-level demographic and electoral statistics.

This paper contributes to a growing literature on the determinants of solar adoption among households and businesses (see for example, De Groote & Verboven, 2019; Gerarden, 2017). To our knowledge, it is the first paper to analyze the role of building codes in limiting the adoption of solar PV. This paper also contributes to a broader literature on the role of building codes in the transition towards a greener economy (Jacobsen & Kotchen, 2013; Kotchen, 2017). Finally, this paper contributes to a strand of literature analyzing the role of building codes in shaping urban environments and preserving the cultural and historical heritage of towns.

## Methods

In the preliminary analysis we use a linear model to study two outcomes, the total installed solar capacity and the number of solar PV installations. For now, we are considering two municipal policies or treatments: Policies that explicitly restrict the installation of solar photovoltaics (either bans or permit requirements) and policies that impose more subtle regulations on how solar photovoltaics can be installed. We use a linear panel fixed effects specification of installed solar capacity (or number of solar PV installations) on the presence of restrictive policies and the presence of any other type of regulation of solar photovoltaics in municipality i in year t. The sample consists of all 1,941 matched municipalities, of which 76 had policies restricting solar adoption, such as bans. We will improve upon this approach using matching methods. Further, we will take advantage of our survey data to study policies that only concern an area within a municipality, for example, a historical part of a town. This allows us to address the identification threat due to unobserved characteristics of municipalities. Utilizing a regression discontinuity design we will be able to estimate the local average treatment effect of solar policies on the adoption of solar energy within municipalities, along the precise geographic borders of an area where the policy is in effect.

## Results

The preliminary results from the linear panel fixed effects specification indicate that municipal policies that restrict the installation of solar photovoltaics reduce the number of solar installations in the average municipality by three. Similarly, a ban reduces the total installed capacity by 176 kilowatts on average. We see this as tentative evidence that municipal building policies play a role in solar adoption that needs to be investigated further.

## Conclusions

As solar energy reaches grid parity in many countries, governments are phasing out their subsidy schemes to promote the installation of solar photovoltaics (PV). In this paper, we assess the role of non-price obstacles to the adoption of solar PV represents, arguably, the new frontier in research and policymaking. We leverage the context of Germany, the country in the world with the highest penetration of solar energy and the most mature market for solar PV, to assess the role of building codes in either supporting or preventing the adoption of solar PV. We combine geolocalized data on about 2,000,000 solar installations with a unique survey on municipalities’ current and past building codes affecting the adoption of solar PV. Our preliminary results indicate that municipal building codes present an obstacle to solar PV adoption.

## References

Creutzig, F., Agoston, P., Goldschmidt, J. C., Luderer, G., Nemet, G., & Pietzcker, R. C. (2017). The underestimated potential of solar energy to mitigate climate change. *Nature Energy*, *2*(9), 17140.

De Groote, O., & Verboven, F. (2019). Subsidies and time discounting in new technology adoption: Evidence from solar photovoltaic systems. *American Economic Review*, *109*(6), 2137–72.

Gerarden, T. (2017). *Demanding innovation: The impact of consumer subsidies on solar panel production costs* (Tech. Rep.). Technical report, Working paper, Harvard University.

Jacobsen, G. D., & Kotchen, M. J. (2013). Are building codes effective at saving energy? evidence from residential billing data in florida. *Review of Economics and Statistics*, *95*(1), 34–49.

Kotchen, M. J. (2017). Longer-run evidence on whether building energy codes reduce residential energy consumption. *Journal of the Association of Environmental and Resource Economists*, *4*(1), 135–153.

REN21. (2018). Renewables 2018 global status report.