

Residential Rent Externalities of Photovoltaic Systems: The Relevance of View

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Motivation: View Matters



Motivation: The View at PV Systems



Research Questions

- *Does the view at PV systems affect residential rents?*
- *Does the external effect of PV systems on residential rents change when considering different view types? How does the external effect compare to the internal effect of PV installations on residential rents?*
- *Is the external effect of PV systems on residential rents driven by the preferences for sustainability in a municipality?*

Data: Sources (1/2)

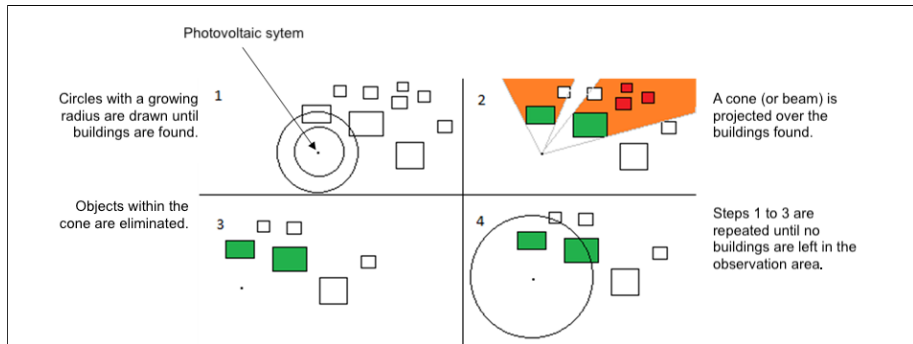
- **Residential Rents:** 621,010 residential rents are given for our study areas in Switzerland from 2004 until 2021 ([real estate advertisements](#) from *Immoscout24.ch* or *Homegate.ch*).
▶ Data: Residential Rents (Descriptives)
▶ Data: Study Areas
 - ▶ Geo-referenced location
 - ▶ Listing date
 - ▶ Dwelling type and characteristics
 - ▶ Number of rooms and scenic view
- **Photovoltaic Systems:** Information on [individual PV systems](#) stems from a geo-database on electricity production facilities provided by the Swiss Federal Office of Energy.
▶ Data: Mapping PV Systems
 - ▶ Geo-referenced location
 - ▶ Date of commissioning
 - ▶ Output/size
 - ▶ Placement (*Sonnendach.ch*)

Data: Sources (2/2)

- **3D Topographical Information:** To create a **3D model of our study areas in Switzerland**, we collect and combine three datasets from the Swiss Federal Office of Topography. ▶ Data: Topographical Model in 3D
 - ▶ *swissAlti3D*: digital elevation model (xyz-file in regular grids).
 - ▶ *swissBuildings3D 2.0*: shapes and overhangs of dwellings.
 - ▶ *swissTLM3D*: landscape model including natural/artificial objects.
- **Municipal Data:** To explore **preferences for sustainability** we collect recent voting results of two referendums in Switzerland as well as other municipal attributes from the Swiss Federal Statistical Office.
 - ▶ Revised Federal Energy Act 2017
 - ▶ Federal CO₂ Act 2021
 - ▶ Number and share of electric vehicles
 - ▶ Solar energy potential (roofs and facades)
 - ▶ Housing vacancy rate

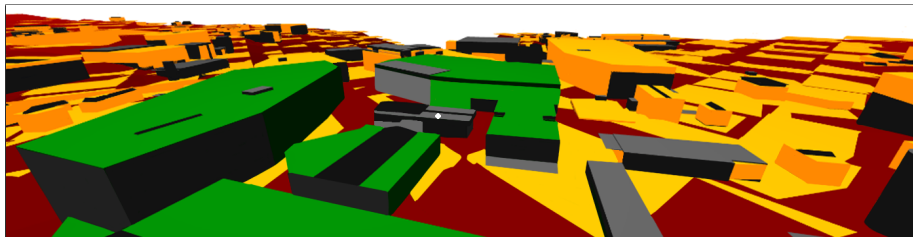
View Modeling: Ray Tracing

We use the **ray tracing** method to model the visibility of all PV installations in our Swiss study areas.



View Modeling: 3D Model

The ray tracing method is applied in the **3D model** of our study areas in **Switzerland**. **Green buildings** have a view at the **PV system (white dot)**.



▶ Data: Topographical Model in 3D

Methodology: Difference-in-Difference Estimation

We specify a **staggered difference-in-difference model** following the inference procedure of Callaway and Sant'Anna (2021) with multiple time periods and variations in treatment timing:

$$\ln(p_{ibt}) = \beta X_{it} + \gamma D_{PVS} + \eta_b + \lambda_t + \epsilon_{ibt}, \quad (1)$$

where $\ln(p_{ibt})$ is the natural logarithm of residential rents. D_{PVS} is a binary indicator that equals one if the observation has a view at a PV installation (after the treatment date). X_{it} comprises a set of hedonic attributes. λ_t are year fixed effects. η_b are building fixed effects. The error term is given by ϵ_{ibt} .

Results: Baseline

Having a **view** at a PV systems **lowers residential rents** by **-1.3%** on average.

	Residential Rents
View at PV System	-0.013*** (0.002)
Scenic view	0.020*** (0.001)
Dwelling type	Yes
Dwelling characteristics	Yes
Year fixed effect	Yes
Building fixed effect	Yes
Observations	621,010
Adjusted within R^2	0.352

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

► Results: Cohort Aggregated Biennial ATET (Rents)

► Results: Time Aggregated Biennial ATET (Rents)

Results: View Types

Distinguishing between various **view types** at PV systems yields insights into drivers of our baseline result.

	Residential Rents	
Likely view	-0.015***	(0.003)
Less likely view	-0.012***	(0.002)
Single PV system	-0.010***	(0.003)
Multiple PV systems	-0.013***	(0.002)
Small PV system	-0.014***	(0.002)
Large and close PV system Δ	0.017***	(0.005)
View w/o own PV	-0.013***	(0.002)
View with own PV Δ	0.067**	(0.028)
View w/o scenic view	-0.011***	(0.002)
View with scenic view Δ	-0.008***	(0.001)
View from apartment	-0.013***	(0.002)
View from house Δ	-0.003	(0.004)

Note: Δ differential, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results: Political Perception (Stated Preferences)

Splitting rental observations across municipality quartiles (lowest to highest share of yes-votes) shows a **causal pathway** of the external effect.

	Residential Rents
Panel A: Revised Federal Energy Act 2017	
View (Yes-votes Q1)	-0.059*** (0.004)
View (Yes-votes Q2) Δ	0.016*** (0.004)
View (Yes-votes Q3) Δ	0.028*** (0.004)
View (Yes-votes Q4) Δ	0.064*** (0.004)
Panel B: Federal CO₂ Act 2021	
View (Yes-votes Q1)	-0.055*** (0.008)
View (Yes-votes Q2) Δ	0.000 (0.009)
View (Yes-votes Q3) Δ	0.015* (0.009)
View (Yes-votes Q4) Δ	0.051*** (0.008)

Note: Δ differential, *p < 0.10, **p < 0.05, ***p < 0.01

Results: Electric Vehicles (Lived Preferences)

Splitting observations across municipality quartiles (lowest to highest number and growth of electric vehicles) shows a similar path of the effect.

	Residential Rents
Panel A: # Registered electric vehicles 2015	
View (# EV (Q1))	-0.083*** (0.012)
View (# EV (Q2): Δ)	0.042*** (0.013)
View (# EV (Q3): Δ)	0.039*** (0.012)
View (# EV (Q4): Δ)	0.074*** (0.012)
Panel B: Change (%) in registered electric vehicles 2015-2021	
View (Change in EVs (Q1))	-0.050*** (0.010)
View (Change in EVs (Q2): Δ)	0.015 (0.015)
View (Change in EVs (Q3): Δ)	0.004 (0.010)
View (Change in EVs (Q4): Δ)	0.040*** (0.010)

Note: Δ differential, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Conclusions

- Our results demonstrate that the view at a PV system leads to a depreciation of residential rents.
- This negative impact varies across different view types. An internal PV system offsets the negative externalities of having a view at a PV system. Seeing large PV systems increases rents as they may benefit surrounding tenants in terms of electricity provision.
- Peoples' lower preferences for sustainability (stated and lived) are a potential driver of negative external effects of viewing PV installations.
- The formulation of policies needs to address the significant, negative externalities by not only accounting for the exposure and, thus, electricity production of a PV system but also its visibility.

Thank you for your attention!

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You can download the latest version of the paper on SSRN:



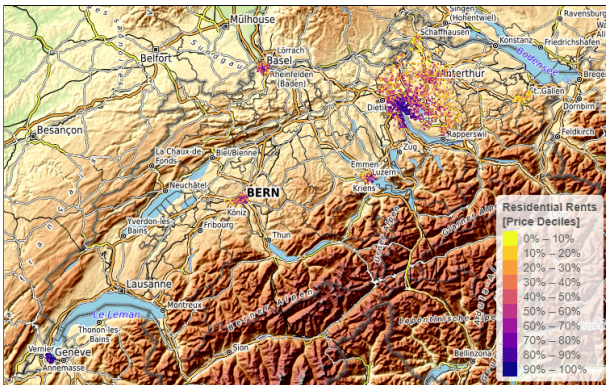
Appendix 1 - Data: Residential Rents (Descriptives)

	Residential rents			
	Mean	S.D.	Min	Max
Rent (CHF/m ² /month)	21.266	6.145	9.000	45.700
log(Rent)	3.019	0.271	2.197	3.822

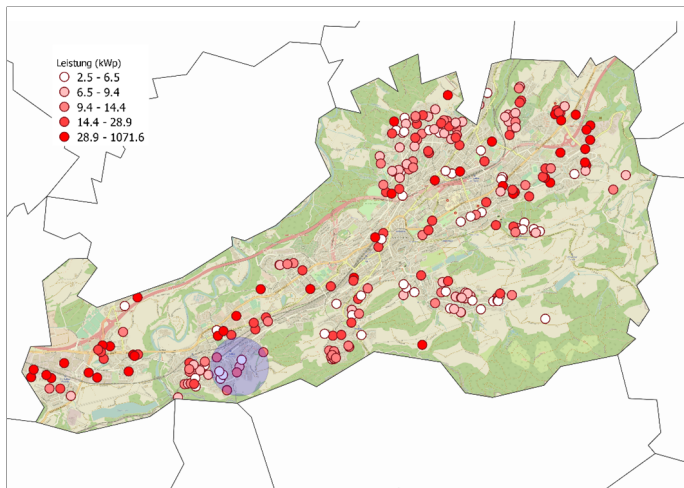
▶ Data: Sources (1/2)

Appendix 2 - Data: Study Areas

The study areas comprise the metropolitan areas of **Basel**, **Bern**, **Geneva**, **Lucerne**, **Schaffhausen**, and **St.Gallen**. In addition, we include the whole canton of **Zurich** in our analysis (see map of rental observations).

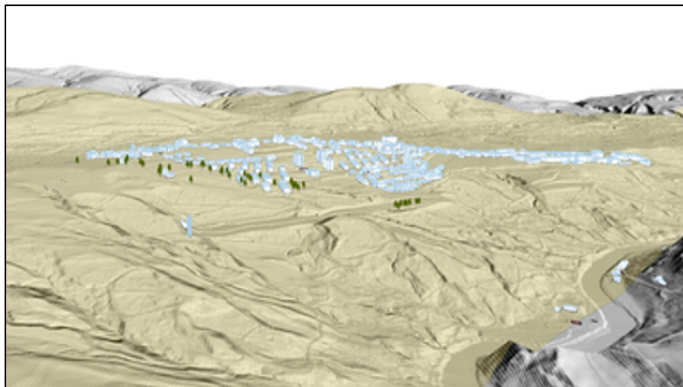


Appendix 3 - Data: Mapping PV Systems



▶ Data: Sources (1/2)

Appendix 4 - Data: Topographical Model in 3D

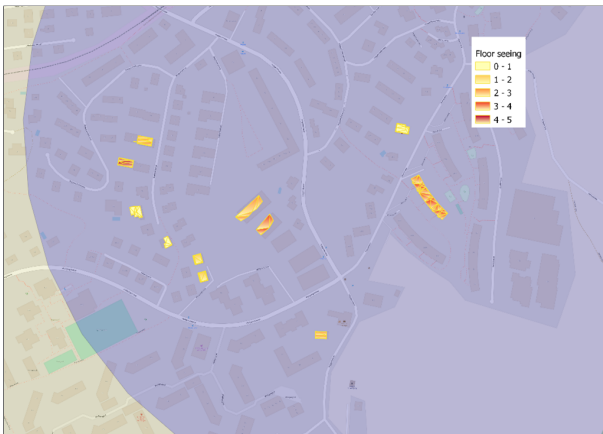


▸ Data: Sources (2/2)

▸ View Modeling: 3D Model

Appendix 5 - View Modeling: Unimpaired View

The number of dwellings with a view is reduced if only buildings with an **unimpaired view** are considered.



► View Modeling: Treatment Group (Baseline)

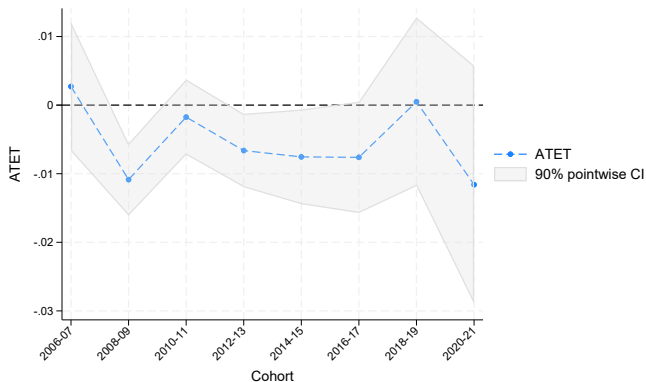
Appendix 6 - View Modeling: View Types

Treatment groups are defined based on **various view types** at PV systems.

	Residential rents (in %)
View (unimpaired and impaired)	0.589
Likely view	0.157
Unlikely view	0.432
Single PV system	0.103
Multiple PV system	0.486
Small PV system	0.535
Large and close PV system	0.054
View w/o own PV	0.584
View with own PV	0.005
View w/o scenic view	0.419
View with scenic view	0.170
View from an apartment	0.574
View from a house	0.015

Appendix 7 - Results: Cohort Aggreg. Biennial ATET

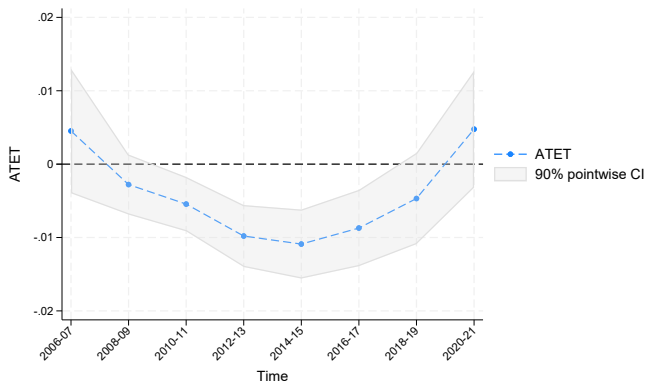
We compute **aggregated ATET** biennially to highlight **different sources of treatment effect heterogeneity** on residential rents across cohorts.



► Results: Baseline

Appendix 8 - Results: Time Aggreg. Biennial ATET

We compute **aggregated ATET** biennially to highlight **different sources of treatment effect heterogeneity** on residential rents across time.



► Results: Baseline

Appendix 9 - Results: Municipal Differences

Splitting housing price observations across municipalities characteristics shows other mechanisms behind the external effect.

	Residential Rents
Panel A: Solar energy production potential (roofs and facades)	
View (Potential (Q1))	-0.082*** (0.014)
View (Potential (Q2): Δ)	0.006 (0.014)
View (Potential (Q3): Δ)	0.037*** (0.014)
View (Potential (Q4): Δ)	0.074*** (0.014)
Panel B: Housing vacancy rate (%) 2006-2021	
View (vacancy (Q1))	-0.001 (0.002)
View (vacancy (Q2): Δ)	-0.009*** (0.003)
View (vacancy (Q3): Δ)	-0.033*** (0.004)
View (vacancy (Q4): Δ)	-0.032*** (0.004)

Note: Δ differential, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$