Some thoughts on the evolution of the solar photovoltaic technology based on previous research

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Sources

- What cost for photovoltaic modules in 2020? Lessons from experience curve models, De La Tour, Glachant, Ménière, 2013, *i3 working paper*
- How do solar photovoltaic feed-in tariffs interact with solar panel and silicon prices? An empirical study, *De La Tour, Glachant*, 2013, i3 working paper

Outline

To use the papers to illustrate two points:

- The learning curve paper
  - To **explain** and to **forecast** may be two contradictory research goals
- The FIT paper
  - **Observationally-small differences** in policy behavior may have strong impacts on the dynamics of the PV technology price

The learning curve paper

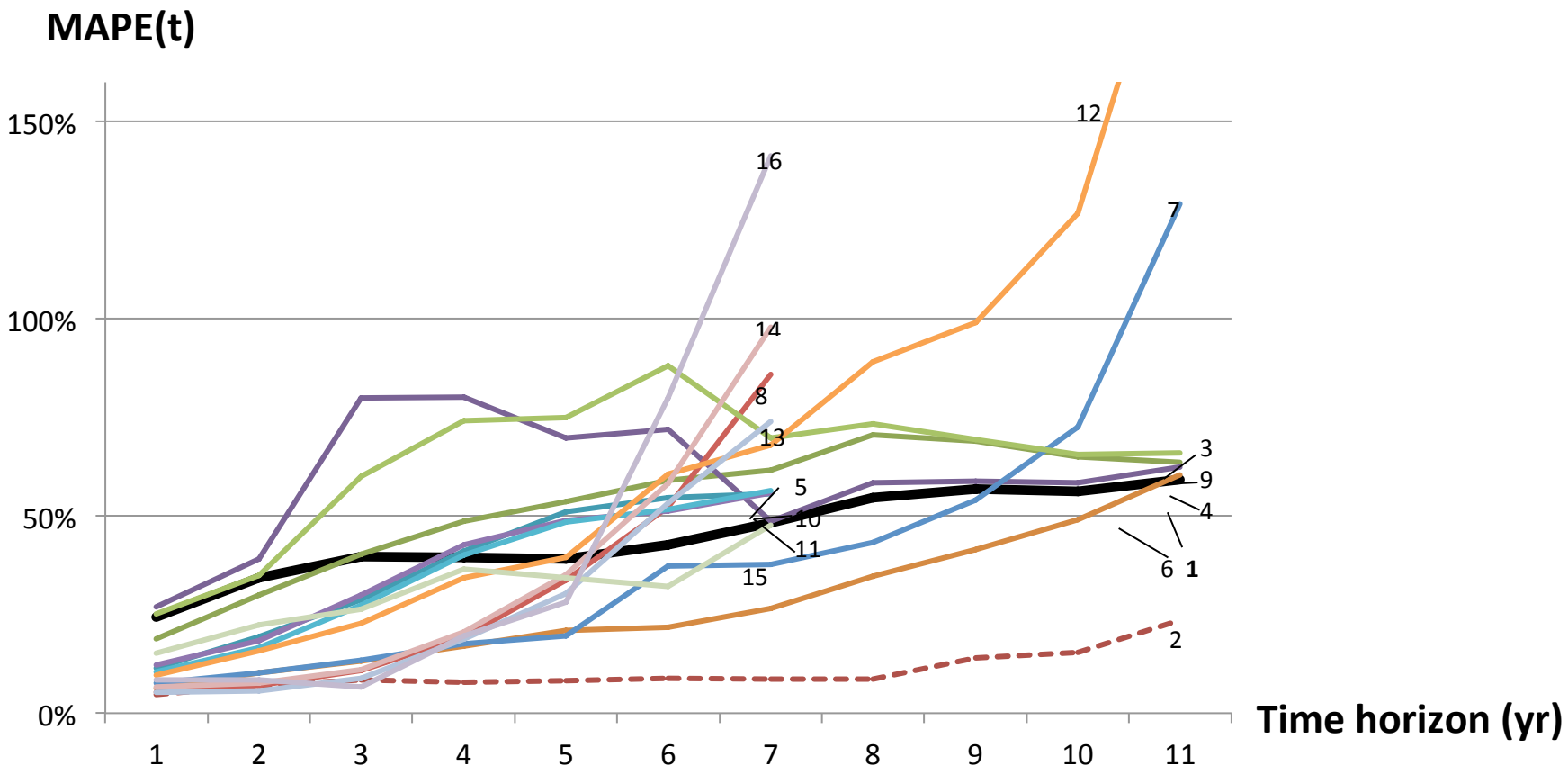
- The question
  - To predict the cost of PV modules out to 2020
- The method
  - We estimate multifactor learning curves with annual data on photovoltaic module prices over the period 1990 – 2011
  - We test different sets of explanatory variables including cumulative production, scale, R&D knowledge stock and input prices for silicon and silver
  - We select the model which minimizes the difference between predicted and actual module prices.

16 sets of independent variables

Cumulative capacity and…

1) No additional variable
2) Si (Silicon)
3) Ar (Silver)
4) Scale
5) R&D
6) Si and Ar
7) Si and Scale
8) Si and R&D
9) Ar and Scale
10) Ar and R&D
11) Scale and R&D
12) Si, Ar, and Scale
13) Si, Ar, and R&D
14) Si, Scale, and R&D
15) Ar, Scale, and RD
16) All (Si, Ar, Scale, and R&D)

Comparison of MAPE for each model,



MAPE(t) is the mean absolute percentage error according to the time horizon t:

$$MAPE_{i,t} = 1/n_t * \sum_{i=1}^{n_t} |P_{i,t} - P_{i,t} / P_{i,t}|$$

Results

- The best model only includes cumulative capacity and silicon price as explanatory variable
- It predicts a 67% decrease of module price from 2011 to 2020.
- Hence increasing the number of explanatory variables does not necessarily improves the predictive power
  - A compromise between omitted-variable bias and multicollinearity
- But necessary if the goal is to study precise policy scenarios
  - Increasing public R&D support
- The fundamental question when choosing the learning curve specification: **What policy questions will be addressed with the results?**

How do FITs and module prices interact with each other?

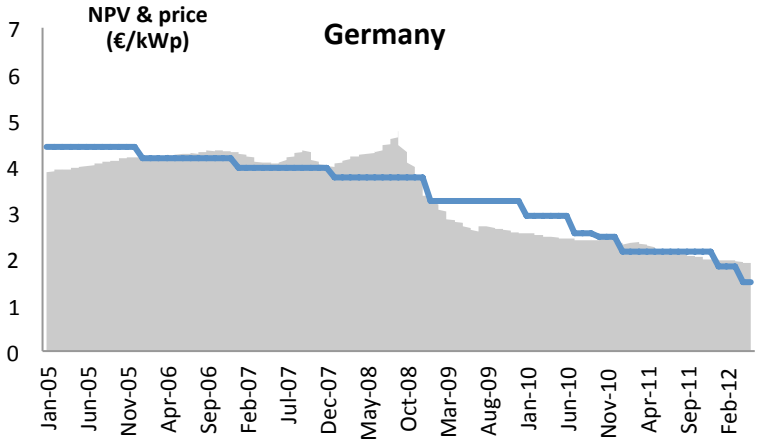
- A FIT subsidizes the demand for PV systems
- In particular, it increases their prices
- It allows PV system producers to collect rents
  - Including foreign manufacturers
- The regulator needs to adjust the FIT in order to minimize these rents while maintaining the incentives to install PV systems

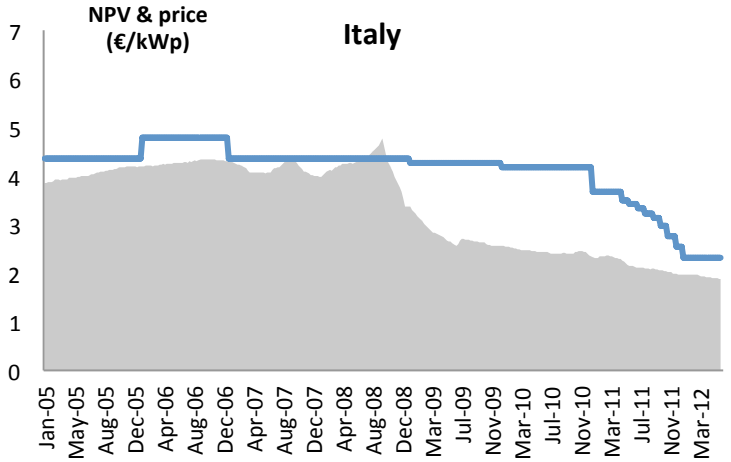
The question: Did the regulators succeed in this exercise? Were they able to limit rents?

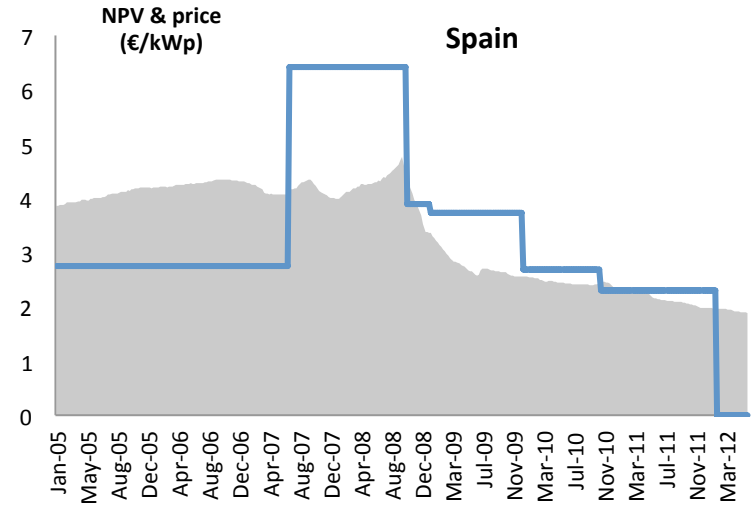
The approach

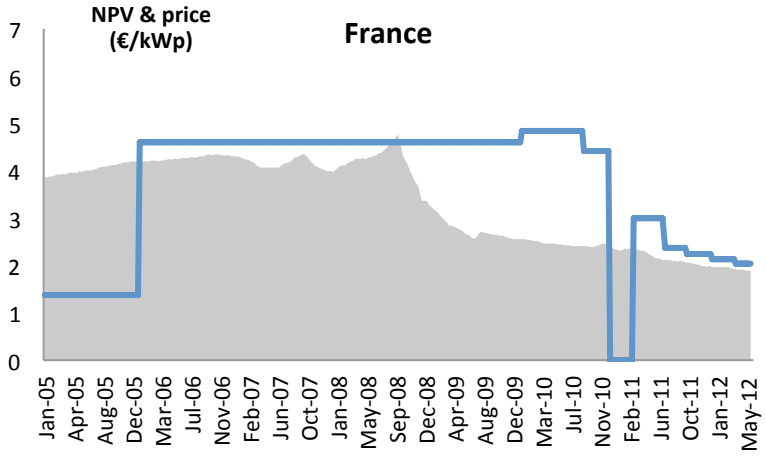
- The interactions between feed-in tariffs, silicon prices and module prices
- Weekly price data and FIT values in Germany, Italy, Spain, and France from January 2005 to May 2012
- Methodology based on Granger causality tests applied to vector autoregressive models (VAR)

Comparison of PV systems price (shaded area) with the value of the FIT (line)

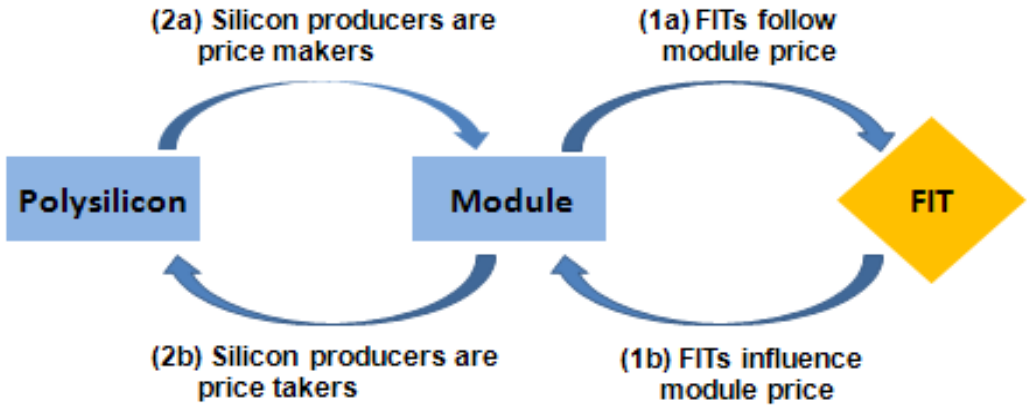








Tested assumptions



- If **Assumption 1a** is true, it means that the regulator is able to adjust the FIT to changes in module price
- If **Assumption 1b** is true, it means that the opposite

Granger causality test results for the period after the silicon shortage

Dependent variable	Excluded	chi2	df	Prob > chi2
ln(*module↓t↑0*)	ln(*silicon↓t*)	3.090	3	0.378
	ln(*FIT↓t*)	2.722	3	0.436
	ALL	7.006	6	0.320
ln(*silicon↓t*)	ln(*module↓t↑0*)	17.47	3	0.001
	ln(*FIT↓t*)	0.567	3	0.904
	ALL	18.69	6	0.005
ln(*FIT↓t*)	ln(*module↓t↑0*)	1.518	3	0.678
	ln(			

Results

- Since the end of the period of silicon shortage in 2009, module price variations cause changes in FITs, and not the reverse.
- This is good news as it suggests that the regulators have been able to prevent FITs to inflate module prices.

- General methodological point:

Observationally-small differences in policy behavior – whether regulators are able to timely adjust their FIT – may generate very different technological trajectories