Learning-by-Doing in Solar Photovoltaic Installations

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Sunshot Conference

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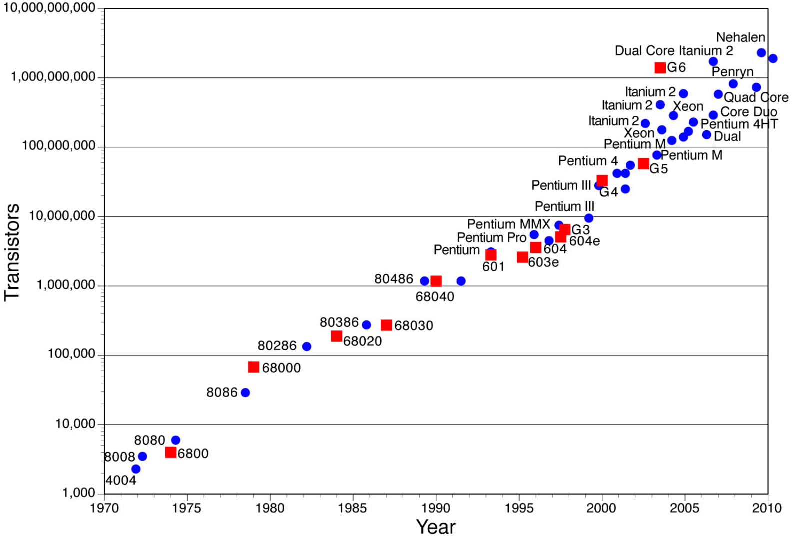
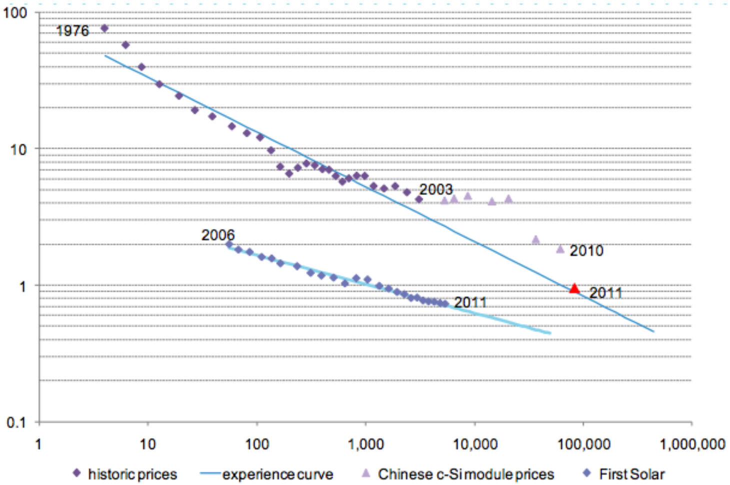
Technology Evolution: Moore's Law



Solar Learning Curve



2011 $, Source: Paul Maycock, Bloomberg New Energy Finance

Learning-by-doing (LBD)

With greater cumulative experience, productivity improves, lowering costs.

Evidence of both “internal” learning (experiential learning) and “external” learning (spillovers).

Spillovers are important for a variety of reasons:

- May influence future market structure.
    - Spillovers undercut barriers to entry and improve market performance (Ghemawat & Spence 1985).
- Such spillovers are a classic positive externality.
    - Government policy may improve economic efficiency (Borenstein 2012; van Benthem et al. 2008).

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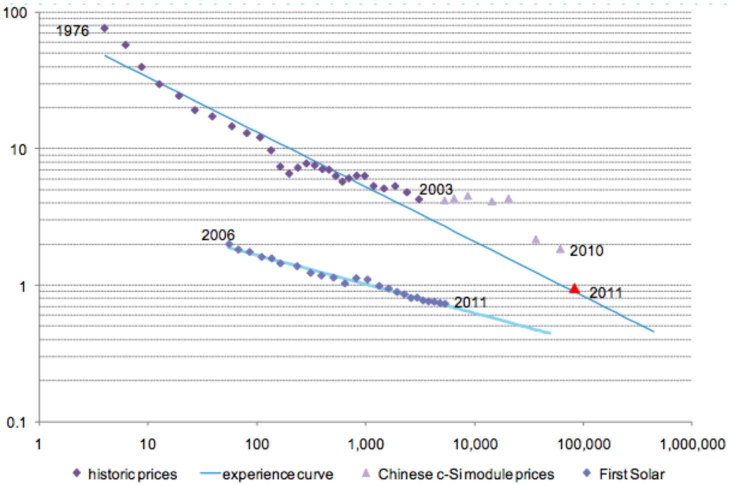

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  - E.g., the California Solar Initiative was motivated by both environmental externalities *and* LBD spillovers at the installation level.
- Solar PV policies are common around the world:
  - Rebates.
  - Feed-in tariffs.
  - Net metering
  - Renewable portfolio standards (RPS).
  - Preferring financing (e.g., PACE).

Our paper

"Learning-by-Doing in Solar Photovoltaic Installations"

Bryan Bollinger and Kenneth Gillingham

Many thanks to Lawrence Berkeley National Laboratory (LNBL) and the US Department of Energy for making this project possible.

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We seek to answer:

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We seek to answer:

- Is there learning-by-doing (LBD) in solar PV installations?
- Is there evidence of learning spillovers?
- How much? What does this imply for the economic efficiency of solar subsidy policies?

Source of LBD: Non-hardware costs

The price of an installation is made up of several parts:

- Hardware costs (on average 54% in 2012 in CA).
  - Panel costs (43%).
  - Inverter costs (11%).
- Non-hardware costs.
  - Labor costs.
  - Transportation costs.
  - Permitting costs
  - Overhead.
- Markup.

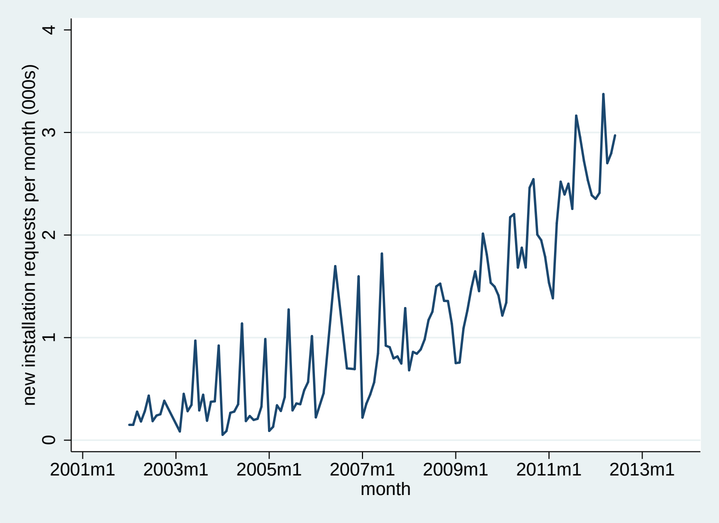
Empirical strategy

- Develop a model of installer pricing behavior in a setting with learning-by-doing and learning spillovers.
- Estimate the model using comprehensive data on CA solar installations.
  - Use variation in cumulative previous installations, prices, hardware costs, and system sizes.
- Control for:
  - Installer's markup possibly increasing with experience
  - Dynamic pricing incentive

Intuition

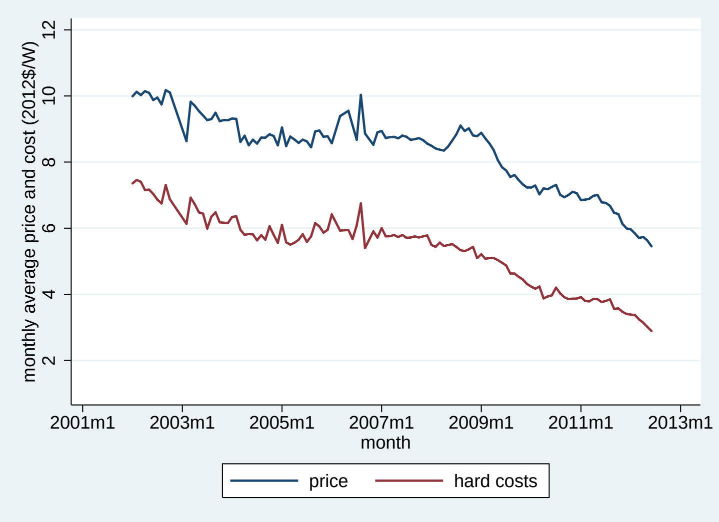
- Non-technology costs: function of experience
- Firm markup due to market power: Also depends on level of the technology costs.
- Dynamic pricing incentive: Also depends on the size of the installation.

Average requested installations per month

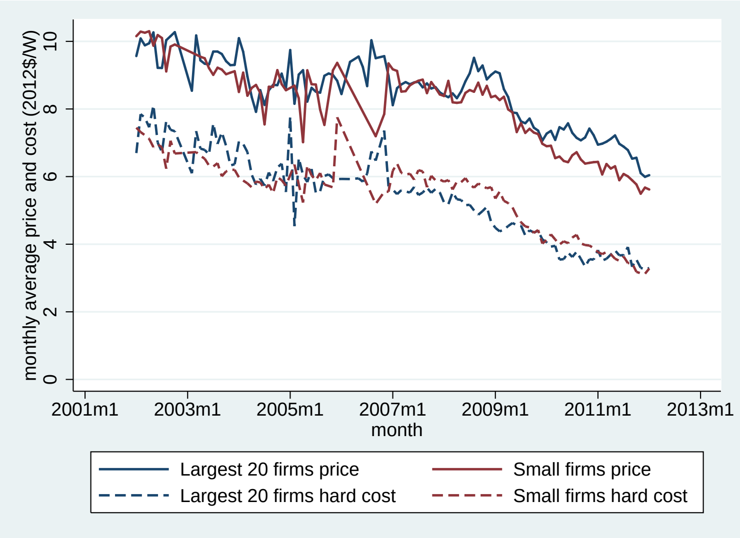


▸ Average System Size Over Time

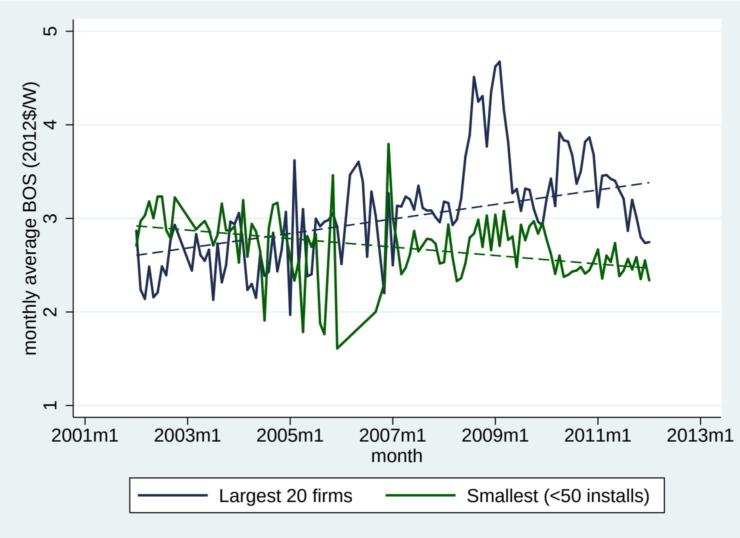
Installation prices over time



Installation prices over time by contractor size



Balance-of-System (BOS) over time



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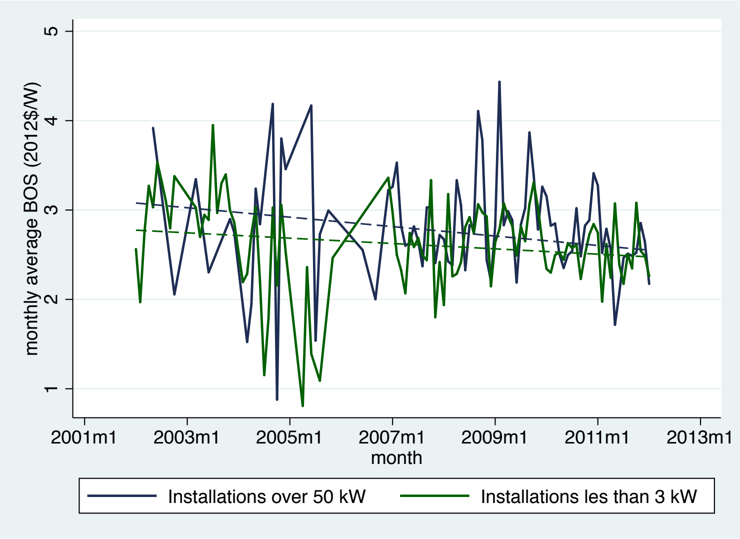
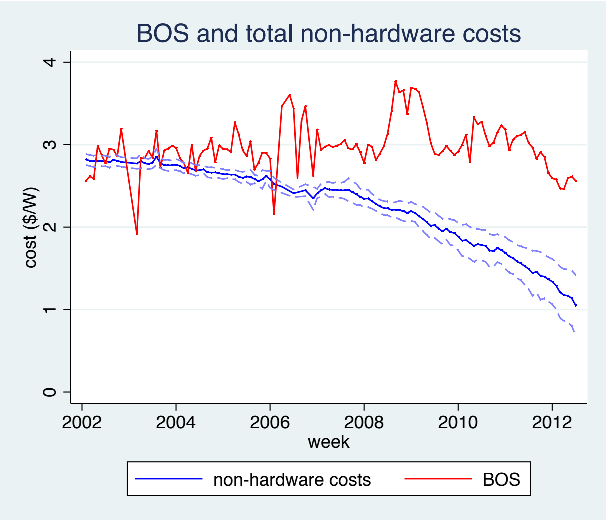


Summary of findings

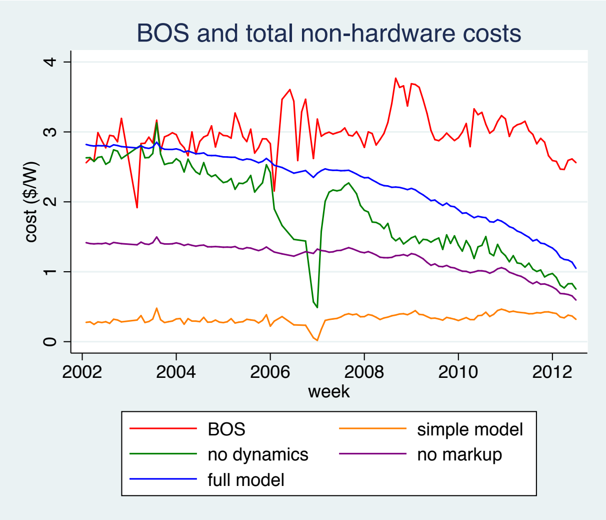
In the CA market, we find:

- Evidence of installer-level LBD:
  - 1,000 own installations in county drop costs by 32%
  - 1,000 own installations outside county drop costs by 16%
- Some evidence of spillovers:
  - 1,000 competitor installations drops cost by 0.63%

BOS vs. non-hardware costs



Model comparison



Implications for policy

- With spillovers, economic efficiency gains is another motivating reason for policies that increase solar adoption.
- With such policies, we should see a resulting decline in BOS costs.

SEEDS diffusion research

Goal of Yale/NYU Study: Determine what drives the effectiveness of Solarize programs.

Partners in SEEDS research:

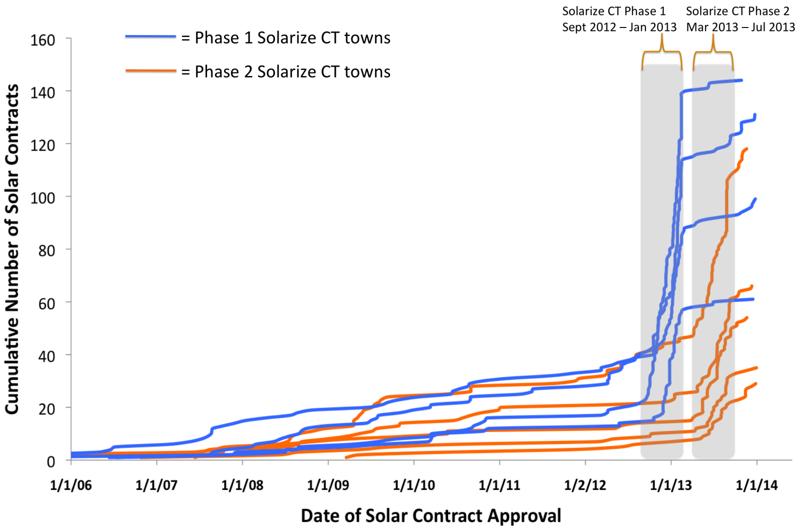
- Yale and NYU
- Smartpower
- CEFIA

Solarize MA/CT

Solarize programs use:

- Volunteer residents (Solar Ambassadors) to coordinate community outreach
- Selection of a vetted installer
- Group pricing
- Presence at community events

Cumulative solar growth in solarize CT towns



Effect of Solarize on prices

- We find a \$0.45 - \$1.30 decrease in price per Watt during Solarize MA in selected towns.
- We find up to a \$0.50 decrease in price per Watt after Solarize MA in selected towns.
- We find some evidence of price spillover effects in adjacent towns.

Concluding remarks

- LBD can drive technological progress
- We find evidence of appropriable and non-appropriable LBD in the installation of solar PV.
- Such findings have important economic efficiency implications for policy.