

# Learning Curves for Photovoltaics

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# Learning curves for photovoltaics

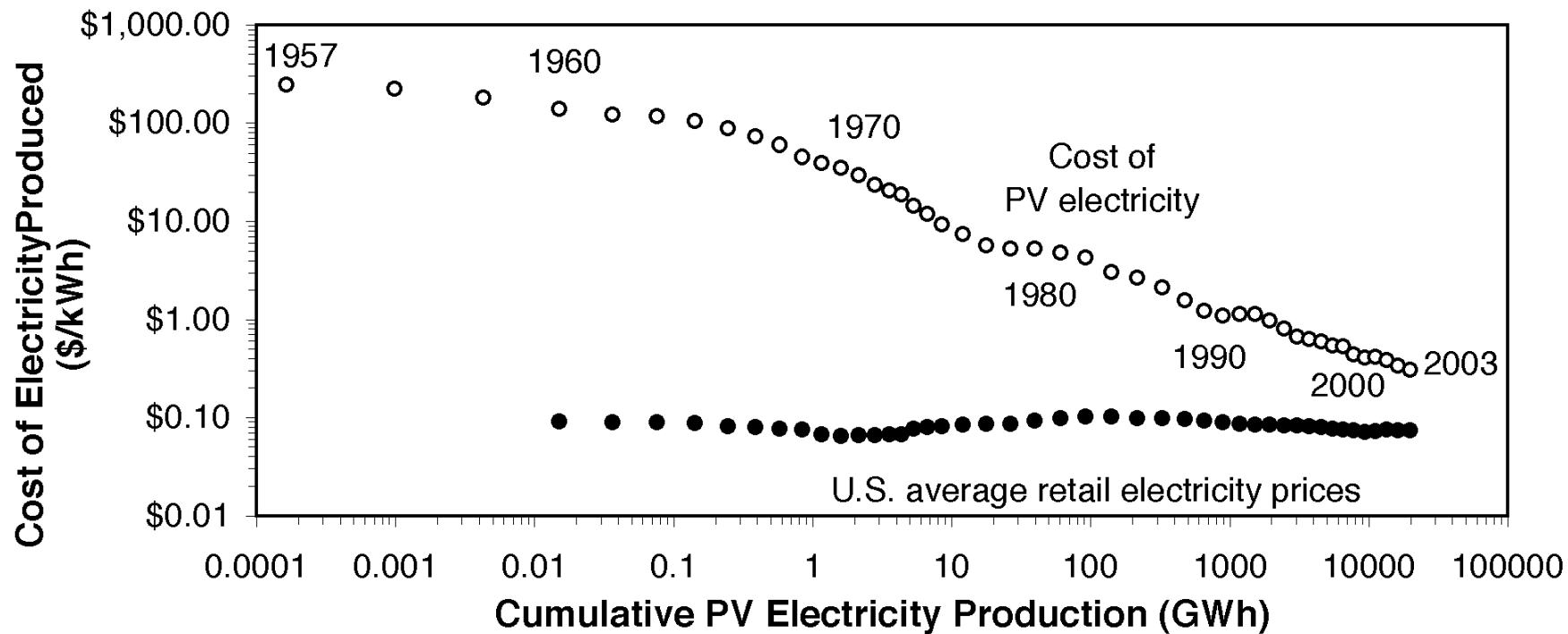
## Session 1 items:

- latest rates
- prices vs costs
- structural changes
- stability of I-rates
- prediction
- geographic scope
- niche markets

## 2 points:

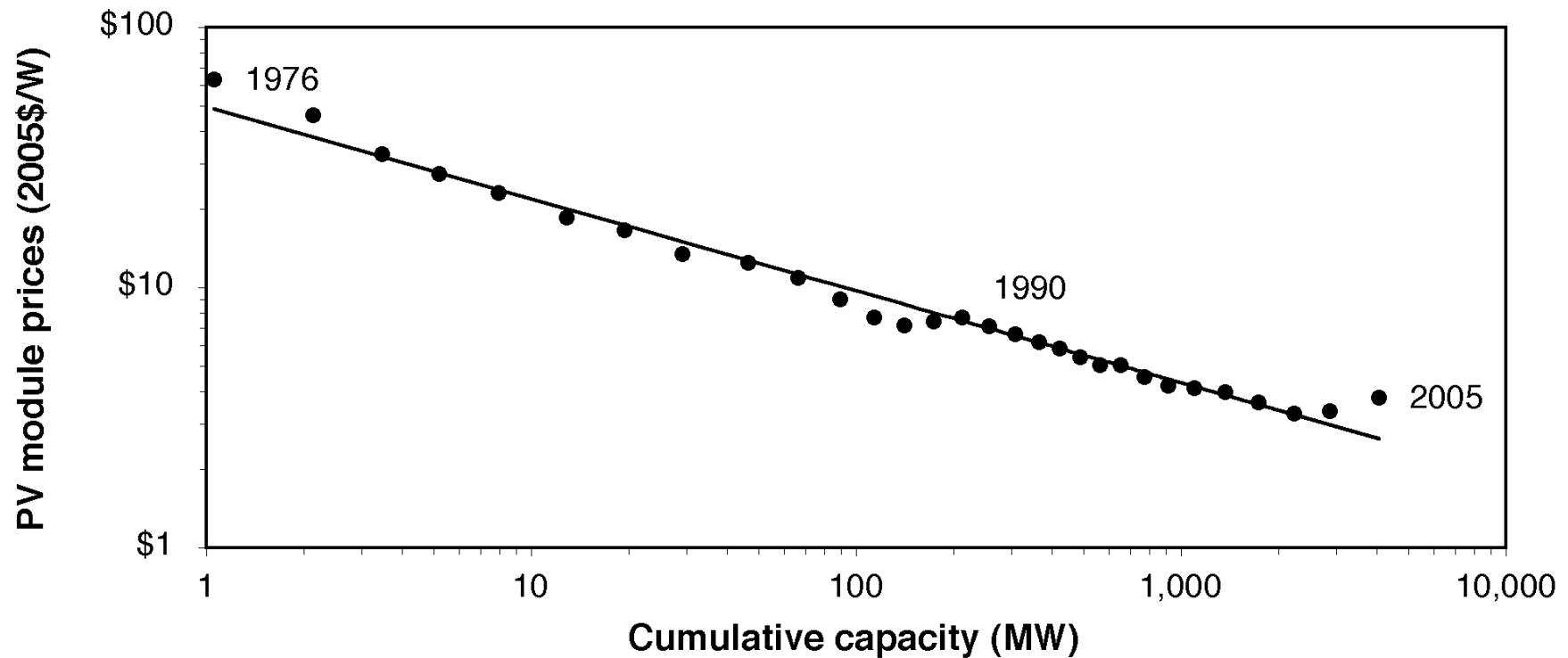
- 1 If experience curves...  
**reliability** of predictions
- 2 If tech  $\Delta$  more generally...  
**expectations**

# Cost of electricity from PV



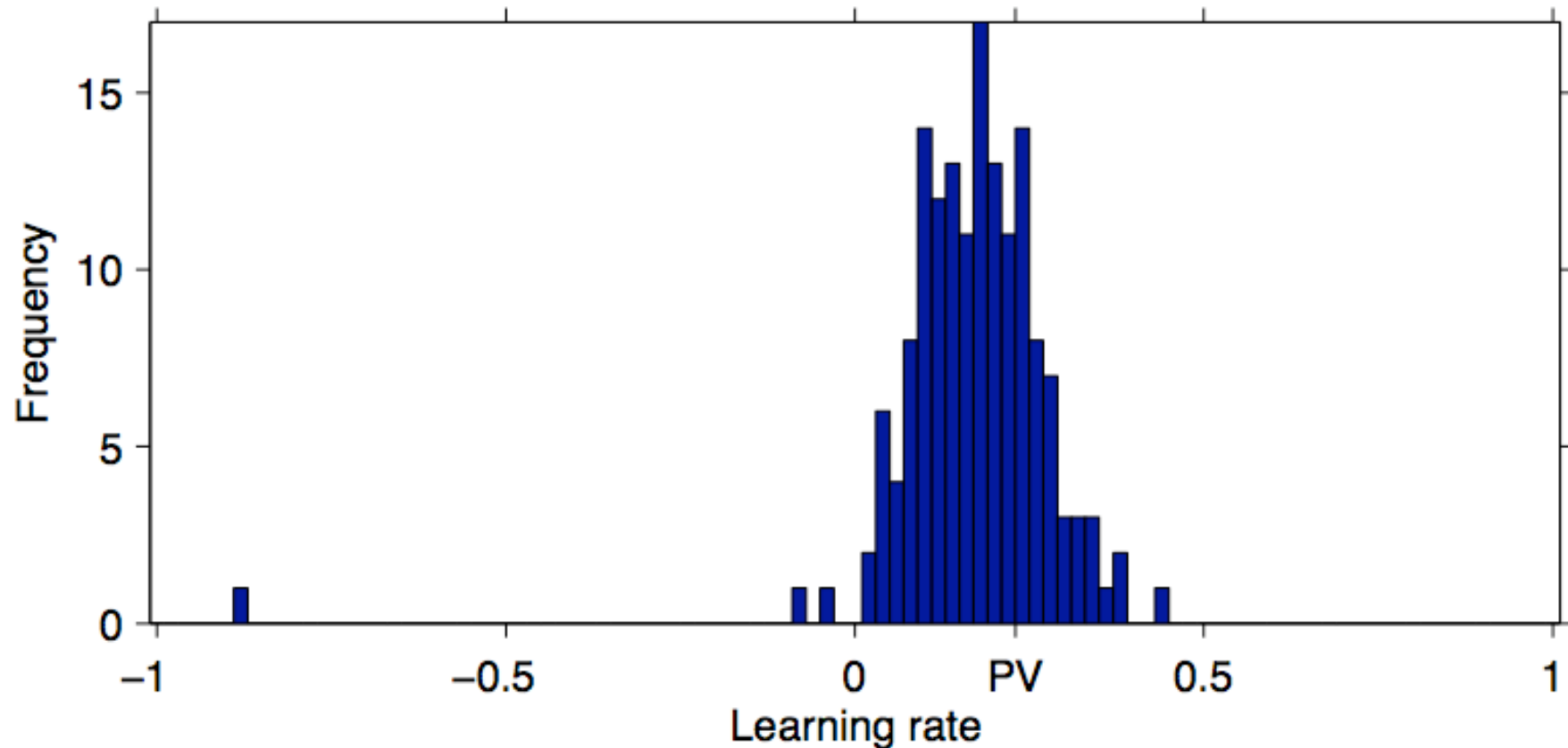
# 1. Reliability of experience curve projections

## Experience curve for PV modules



# 1. Reliability of experience curve projections

Frequency distribution of learning rates calculated in 156 learning curve studies.

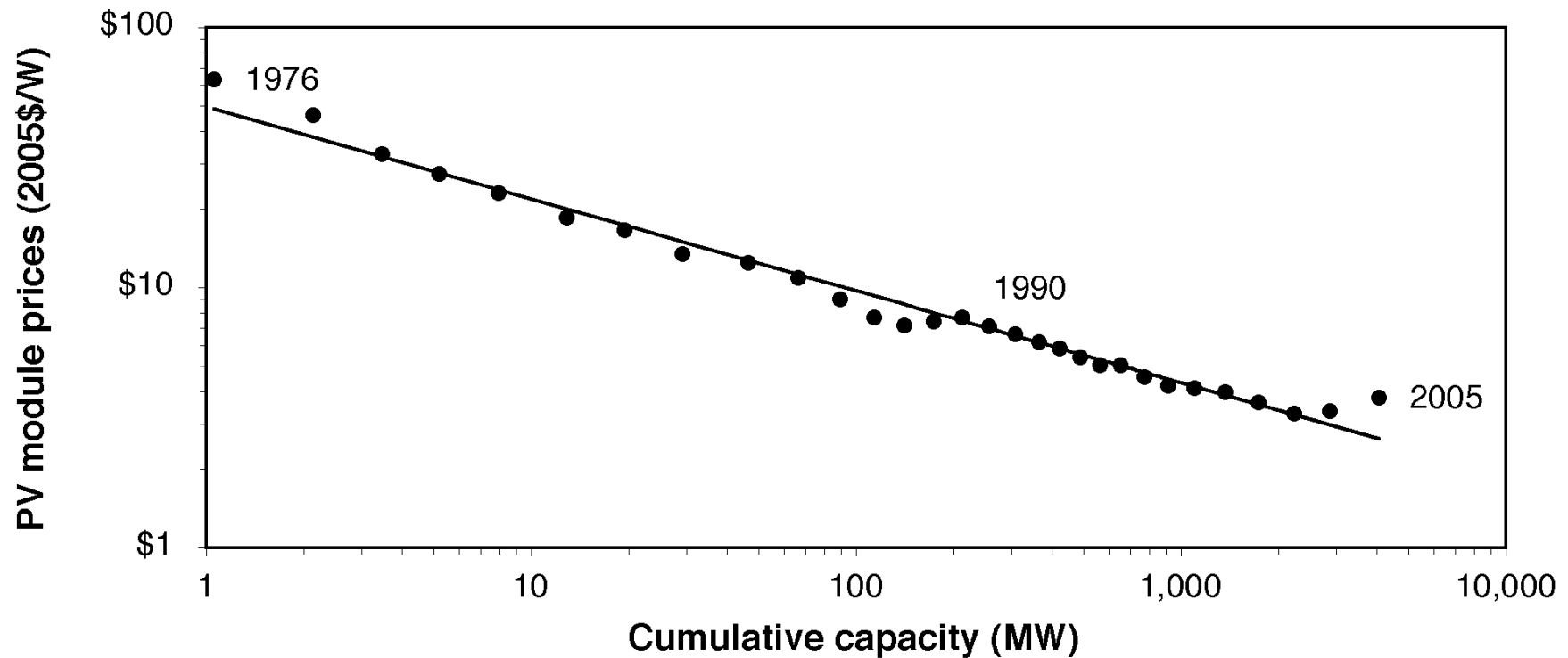


Data: Dutton and Thomas (1984); McDonald and Schrattenholzer (2001); Nemet (2007)

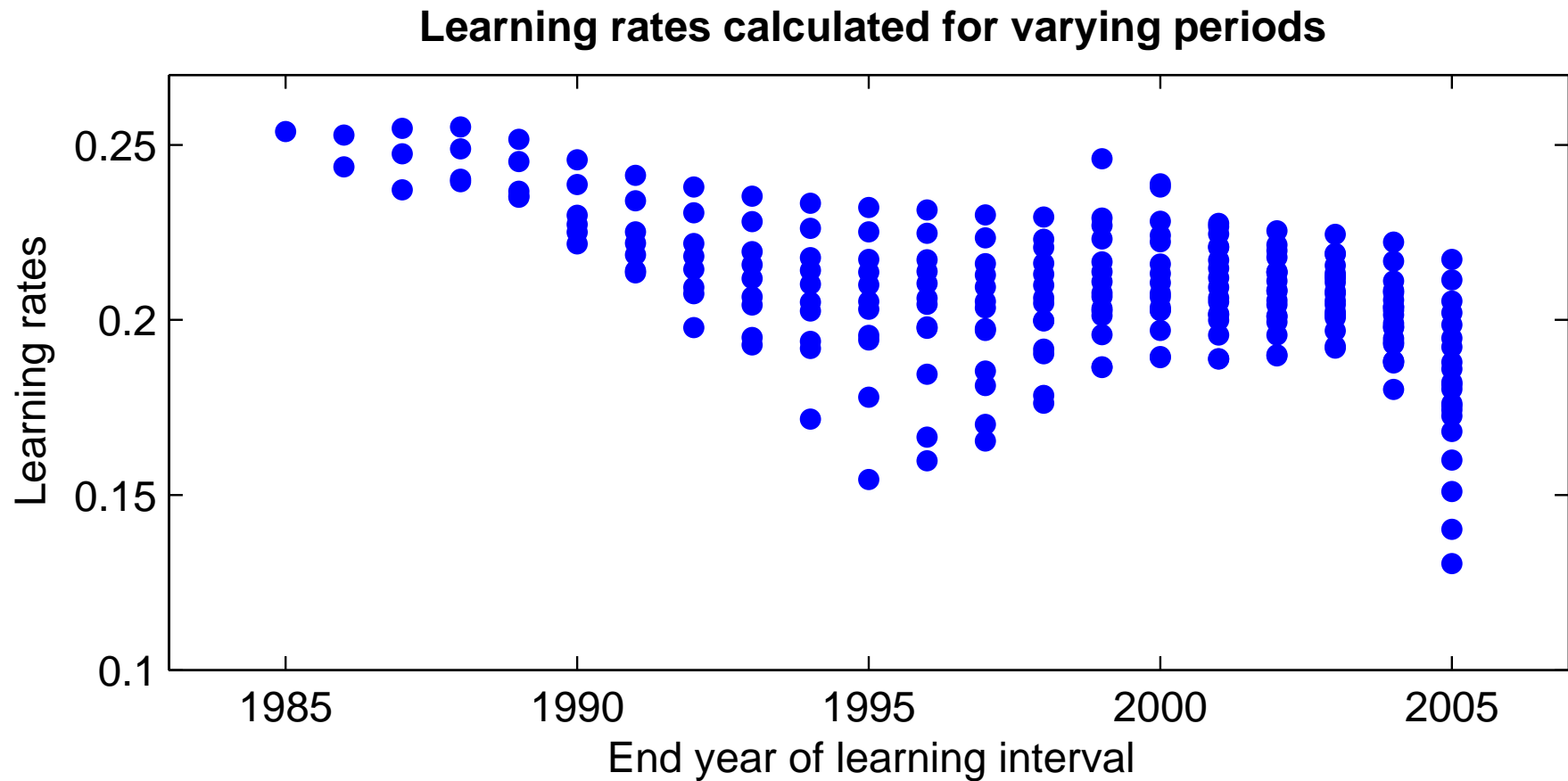


# 1. Reliability of experience curve projections

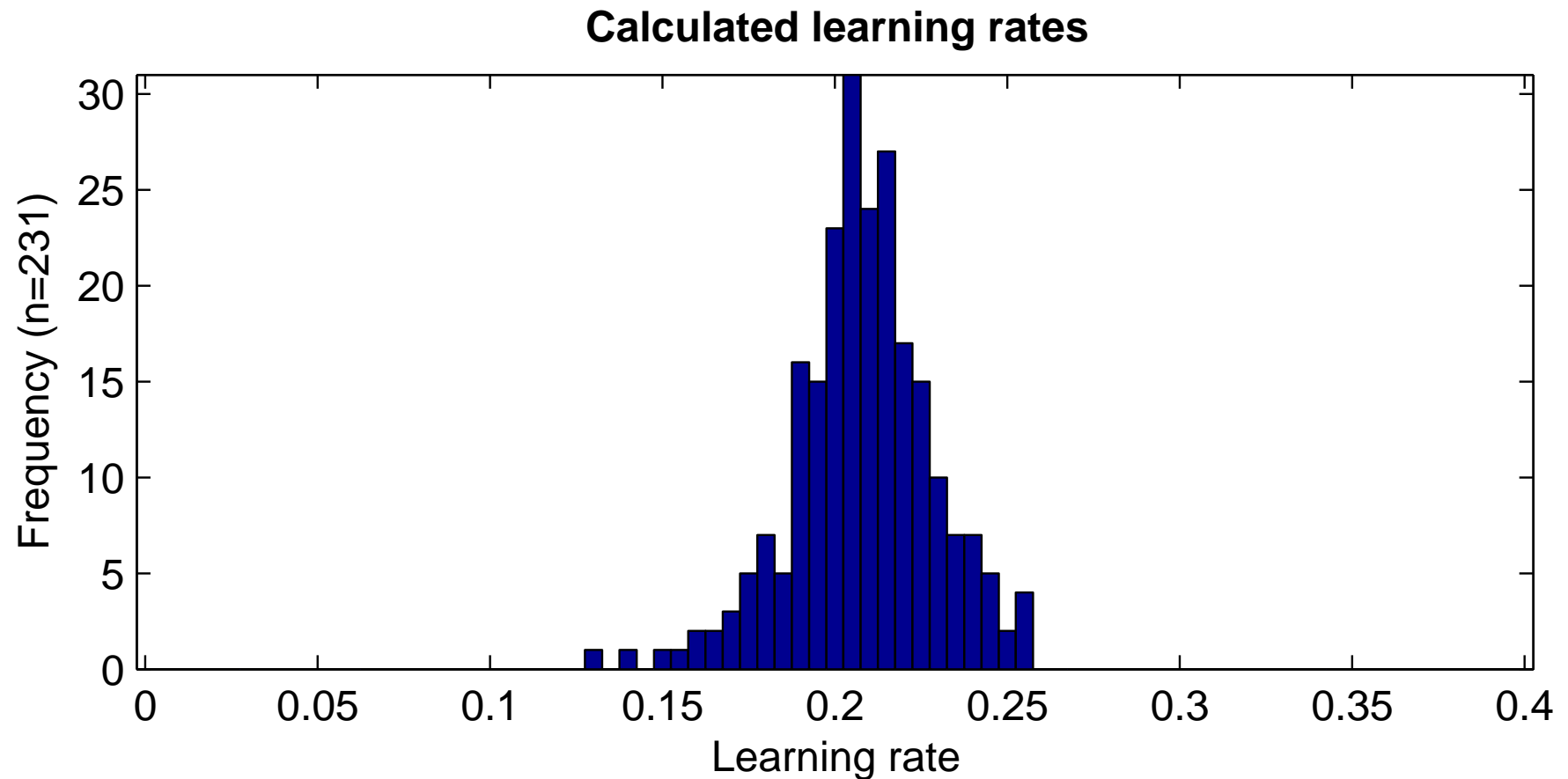
## Experience curve for PV modules



# 1. Reliability of experience curve projections



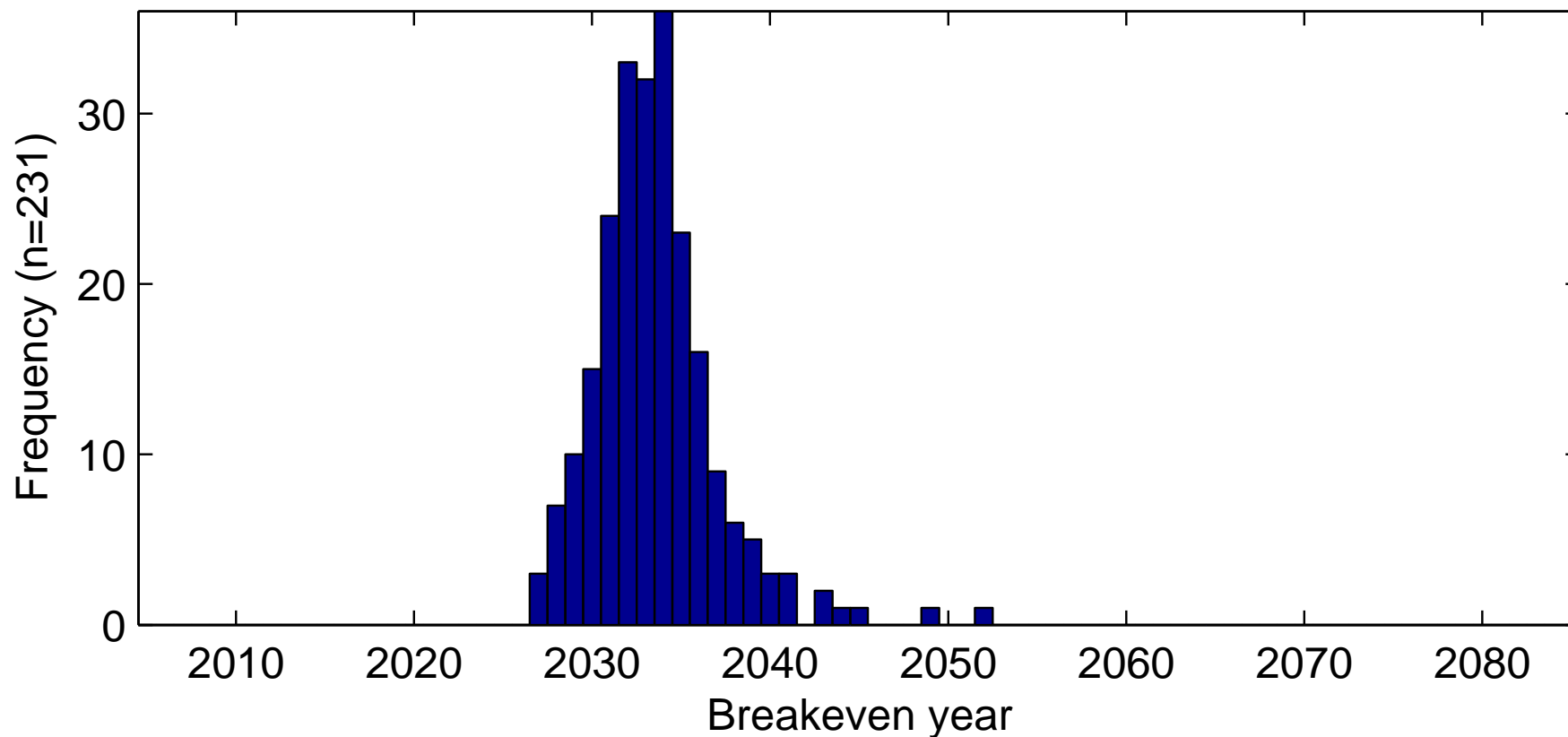
# 1. Reliability of experience curve projections



5th to 95th percentile = 0.17 to 0.24

# 1. Reliability of experience curve projections

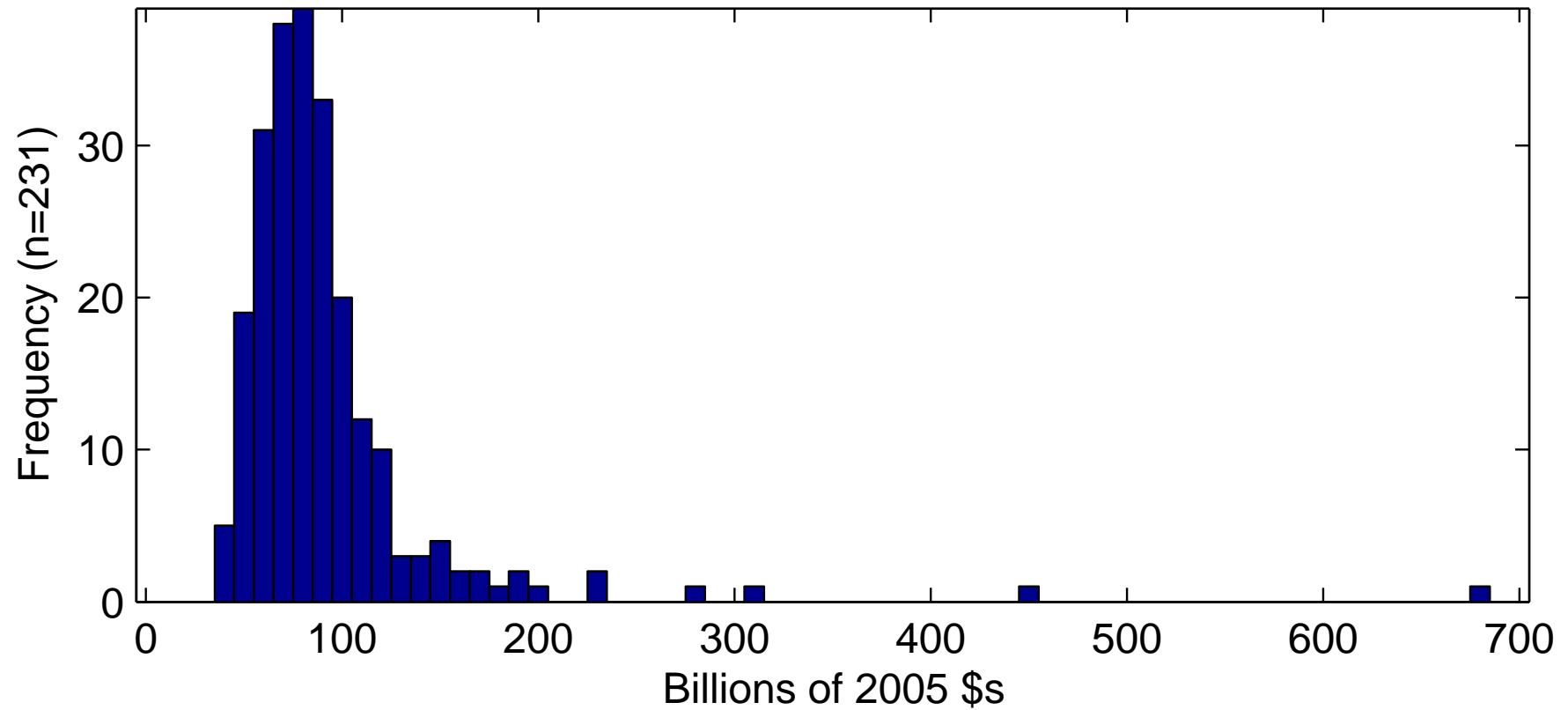
Year at which price of PV equals that of competing technology



5th to 95th percentile = 2029 to 2040

# 1. Reliability of experience curve projections

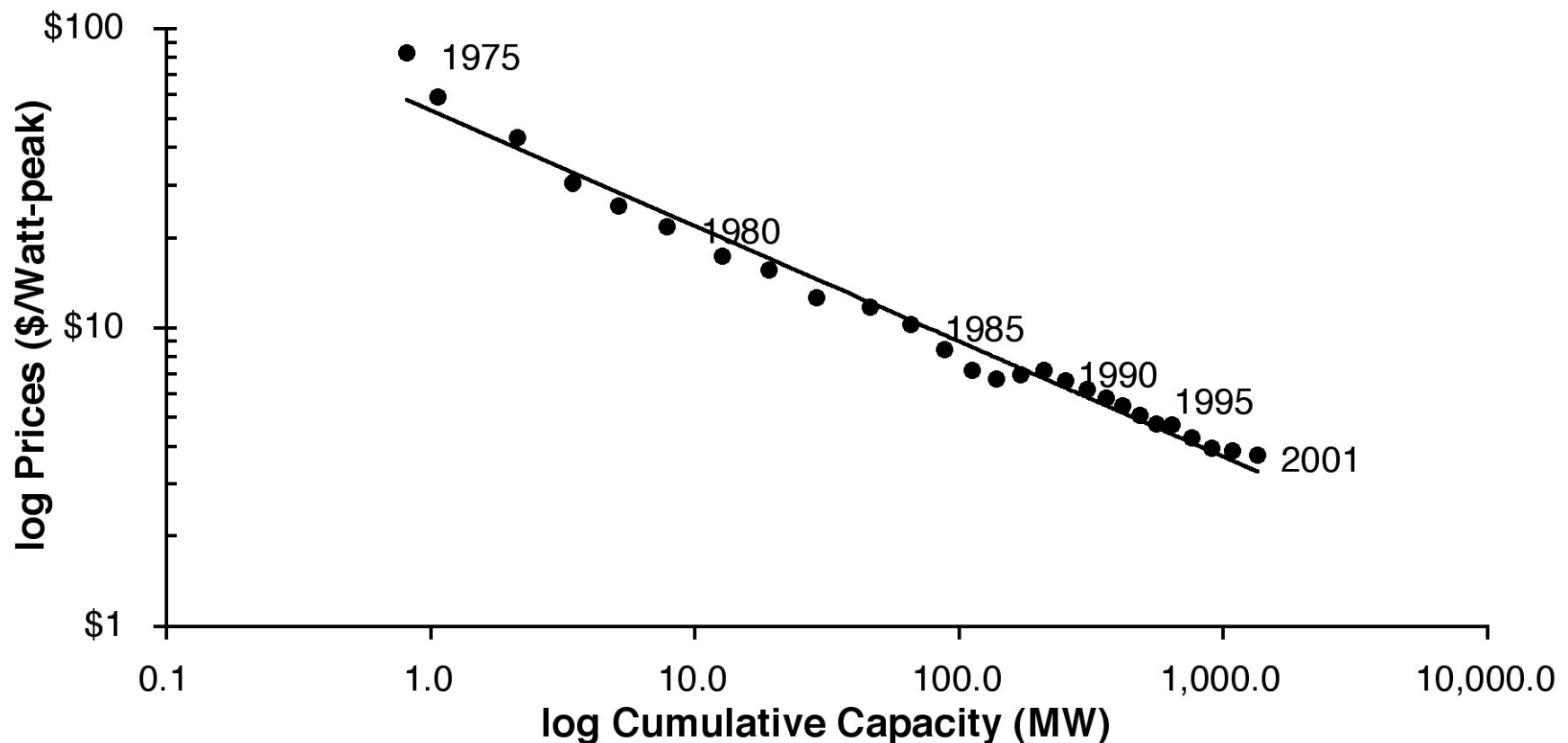
Cost to subsidize PV through breakeven



5th to 95th percentile = \$50b to \$166b

## 2. Decomposition of cost-reductions

- Which factors were most important in reducing cost?
- What were the primary drivers of change in those factors?



## 2. Decomposition of cost-reductions

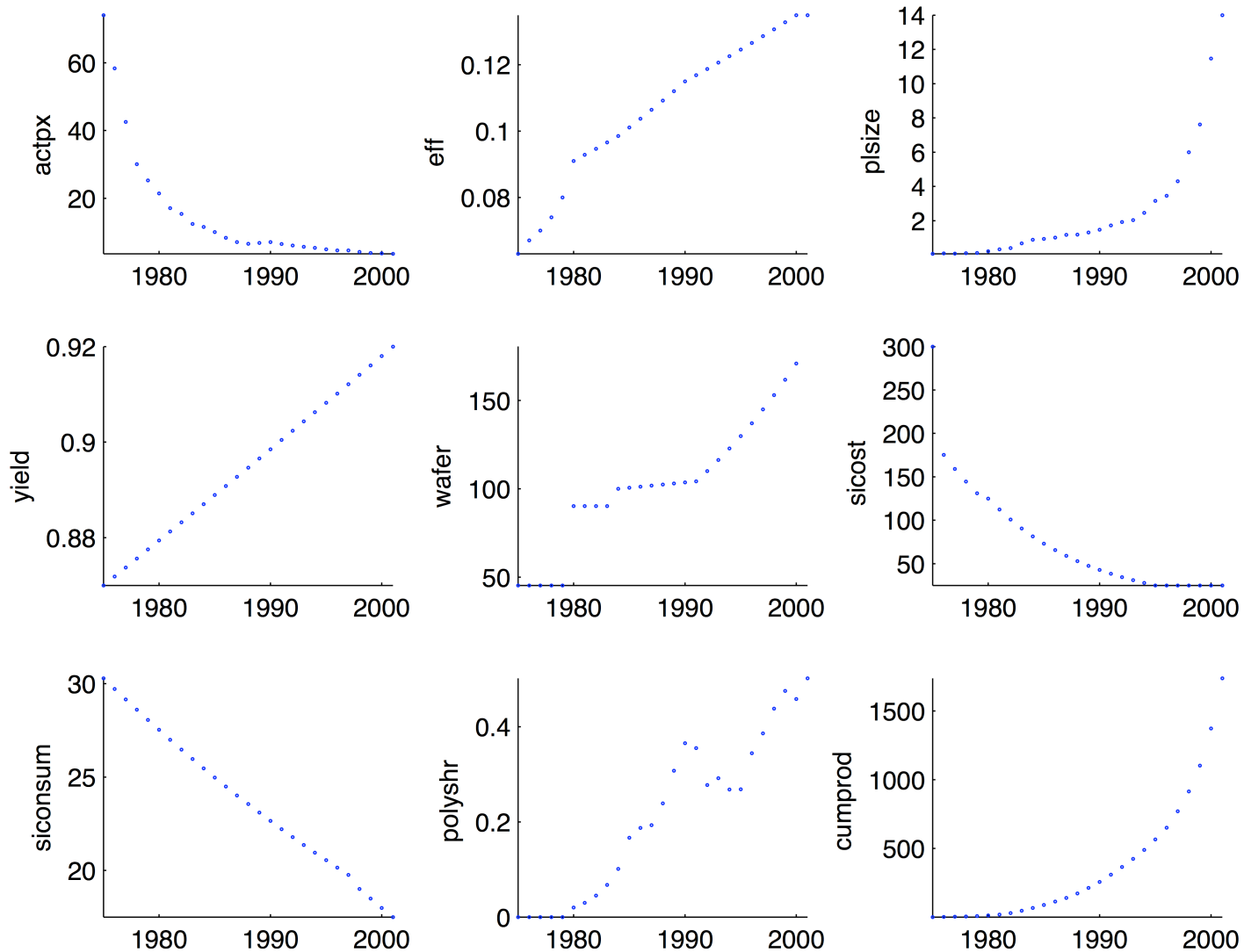
### Questions:

- Which factors were most important in reducing cost?
- What were the primary drivers of change in those factors?

### Approach:

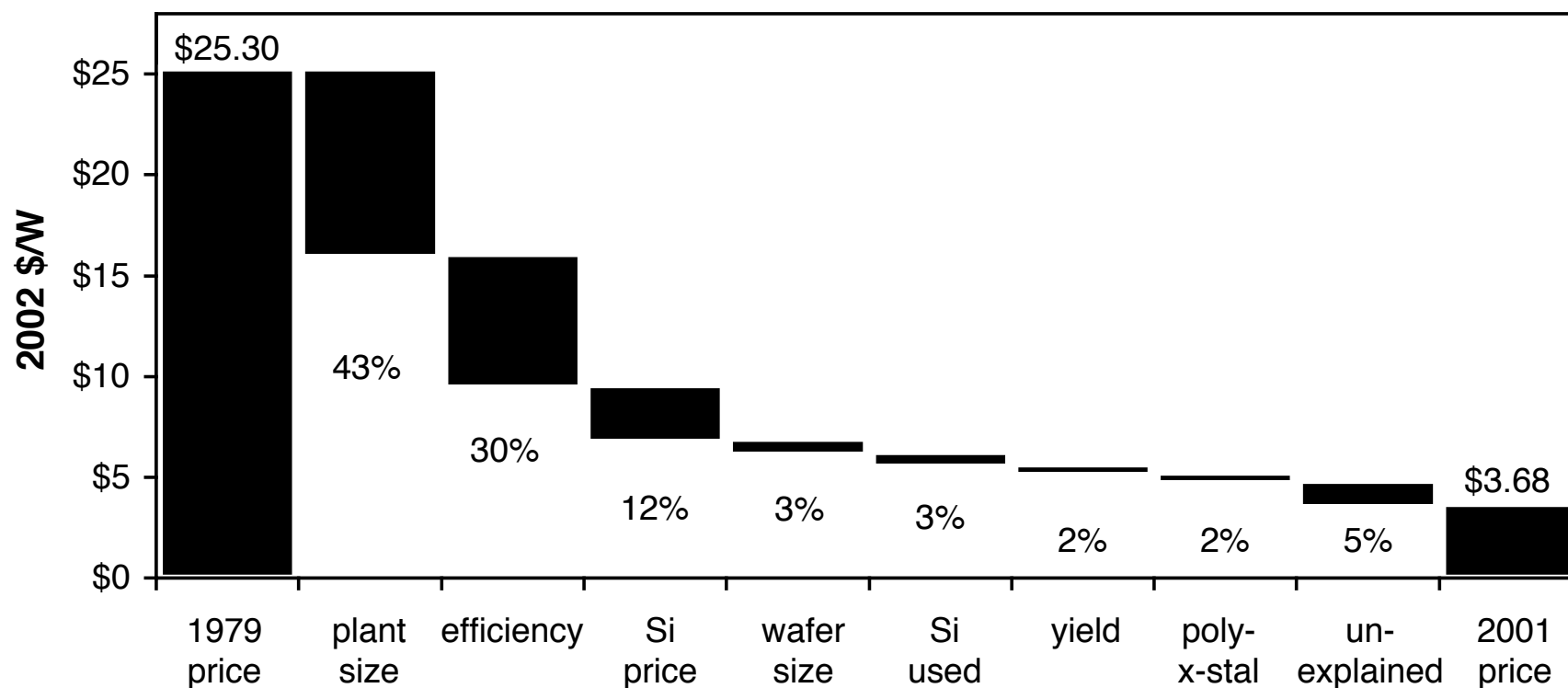
- 1 Identify technical and economic factors
- 2 Time-series data on each factor
- 3 Model impact of factors
- 4 Assess influence of experience, etc.

## 2. Change in each factor 1975-2001



## 2. Model results: contribution of each factor

Portion of cost reduction accounted for by each factor,  
1980-2001



## 2. Drivers of change in cost-reducing factors

Learning-by-doing (lbd) only weakly explains change in the most important factors. . . other drivers play a role

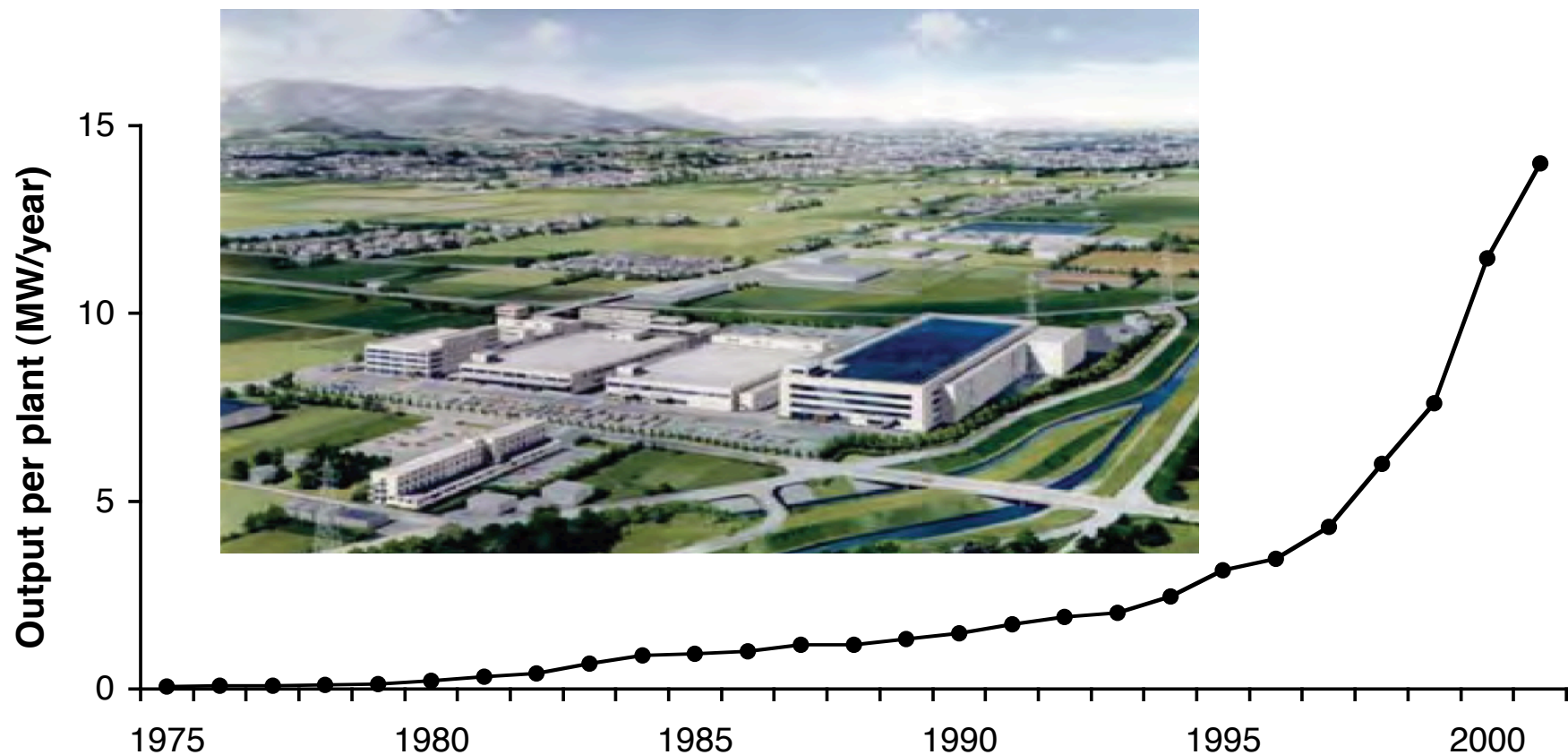
| Factor        | Cost impact | Drivers of change in each factor   |
|---------------|-------------|------------------------------------|
| Plant size    | 43%         | Expected future demand             |
| Efficiency    | 30%         | R&D, some lbd for lab-to-market    |
| Silicon cost  | 12%         | Spillover benefit from IT industry |
| Wafer size    | 3%          | Strong lbd                         |
| Si use        | 3%          | Lbd, but spillover for wire-saws   |
| Yield         | 2%          | Strong lbd                         |
| Poly share    | 2%          | New process, lbd possible          |
| Other factors | 5%          | Not examined                       |

Nemet, G. F. (2006). "Beyond the learning curve: factors influencing cost reductions in photovoltaics." **Energy Policy** 34(17): 3218-3232.



## 2. Did experience enable increase in plant size?

- Several firms make rapid expansions with little experience.
- Biggest plants built by firms with access to capital.



Managing risk of large, uncertain investments w/ lengthy payoffs more important than overcoming technical problems.

If we are going to rely on experience curves. . .

- ① Need to be explicit about **reliability** of predictions
- ② Policy decisions should reflect **variation** in L-rates

If we are going to rely on experience curves. . .

- 1 Need to be explicit about **reliability** of predictions
- 2 Policy decisions should reflect **variation** in L-rates

If we consider the drivers of technological change itself. . .

- Need to create **incentives for investments** in cost-reducing activities
  - **Investments** drive cost reductions
  - **Expectations** about future demand drive investment
  - **Government activities** affect these expectations
  - . . . and perceptions of risk

Extra slides...

# Experience curves to predict change in costs

(Wright 1936, Arrow 1962, Conley 1970)

$$Cost_t = Cost_0 \left( \frac{q_t}{q_0} \right)^{-b}$$

$q$  = cumulative capacity,  $b$  = learning coefficient

## Advantages

- Data availability
- Model consistent with narratives
- High goodness-of-fit
- Dynamic predictions
- Single parameter

## Limitations

- Sensitive to timing
- Discontinuities
- Technical constraints
- Highly aggregated
- Other causal factors
- 1-dimensional quality



# Prices vs. costs: change in competition

1975-1979: from 2 firms to dozens.

