Investment Incentives in Tradable Emissions Markets with Price Floors

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Motivation

- Important tradable emissions markets, such as EU ETS and Regional Greenhouse Gas Initiative (RGGI), have been subject to **emissions uncertainty** and (extremely) **low allowance prices**
- Low allowance prices undermine expected return on investment and incentives for technological innovation in abatement technology (Burtraw et al. 2010; Taylor 2012)
- **Price floors** can guard against the threat of low allowance prices and under-investment in abatement technology (Roberts & Spence 1976; Philibert 2009; Wood and Jotzo 2011)
- Allowance prices likely to be determined by price floors (and ceilings) rather than allowance supply because of large uncertainty in BAU emissions (Borenstein et al. 2019)

Previous Literature

- Theoretical and empirical literature on price floors and effect on investment in abatement technology is limited and non-integrated
- Theoretical literature
  - Analysis of alternative price stabilization mechanisms (Fell et al. 2012; Grüll & Taschini 2011)
  - Relationship between price controls and permit banking (Fell & Morgenstern 2012)
  - Optimal design of emissions markets with price controls and enforcement (Stranlund & Moffitt 2014), and co-pollutants (Stranlund & Son 2019)
- Experimental literature
  - Price controls in laboratory settings (Isaac & Plott 1981; Smith & Williams 1981)
  - Design of emissions markets and permit price risk (Stranlund et al. 2014; Holt & Shobe 2016; Perkis et al. 2016; Friesen et al. 2019; Salant et al. 2020)
- Price controls and investment literature
  - Normative study on optimal design of emissions markets with price controls (Weber & Neuhoff 2010)
  - Real options model to study impact of price floor on timing of investment in low-carbon technology in electricity sector (Brauneis et al. 2013)
- Environmental policy and induced innovation (e.g., Requate & Unold

Our Contribution

- We **develop theory** that predicts firms' investment incentives in abatement technology for emissions trading markets featuring cost uncertainty and regulated by price floors

- We **employ an experimental tradable emissions market** to test the theory

- **Main lesson (theoretical *and* experimental):** Compared to an unregulated market, investment incentives are greater in a market with a price floor in place

Theoretical Model: Marginal Abatement Costs (MAC)

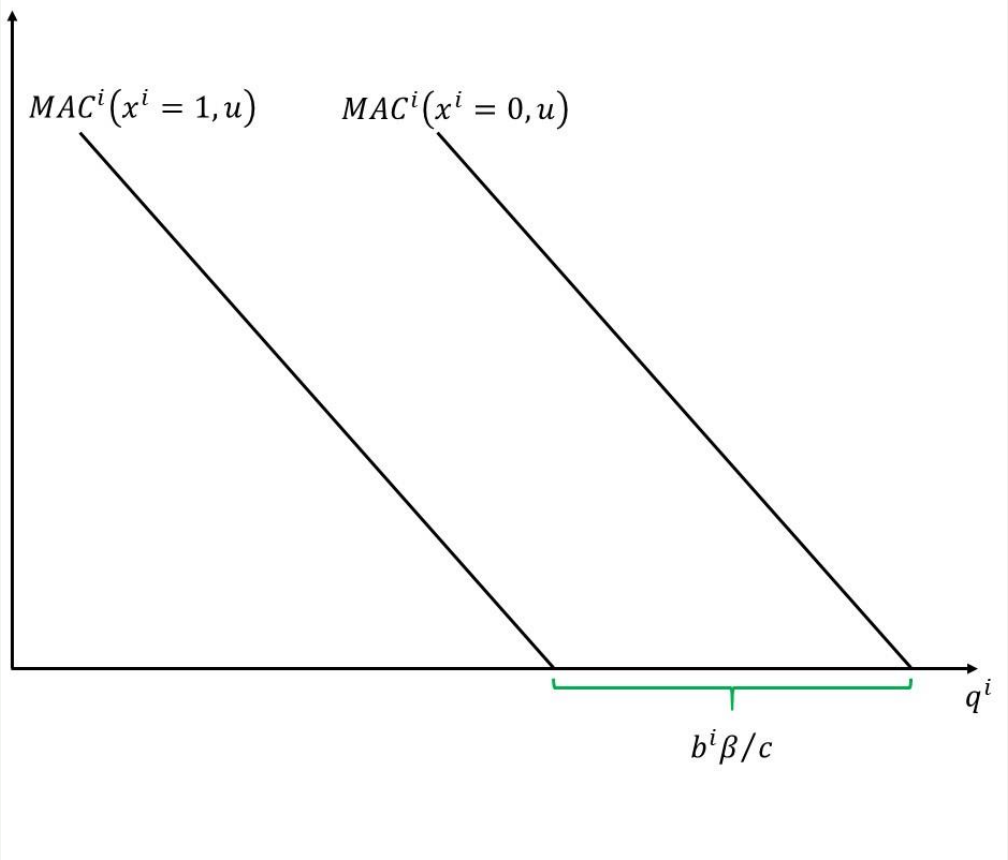
Firm's MAC function

$$MAC^i(x^i, u) = b^i(1 - \beta x^i) + u - cq^i$$

b^i, c intercept and slope parameters
q^i emissions
u random variable with $\mathbb{E}(u) = 0$

$x^i \in \{0,1\}$ investment in technology that shifts MAC^i down

β % reduction in MAC^i from investment



$b^i\beta/c$ — reduction in firm's unregulated level of emissions from investment

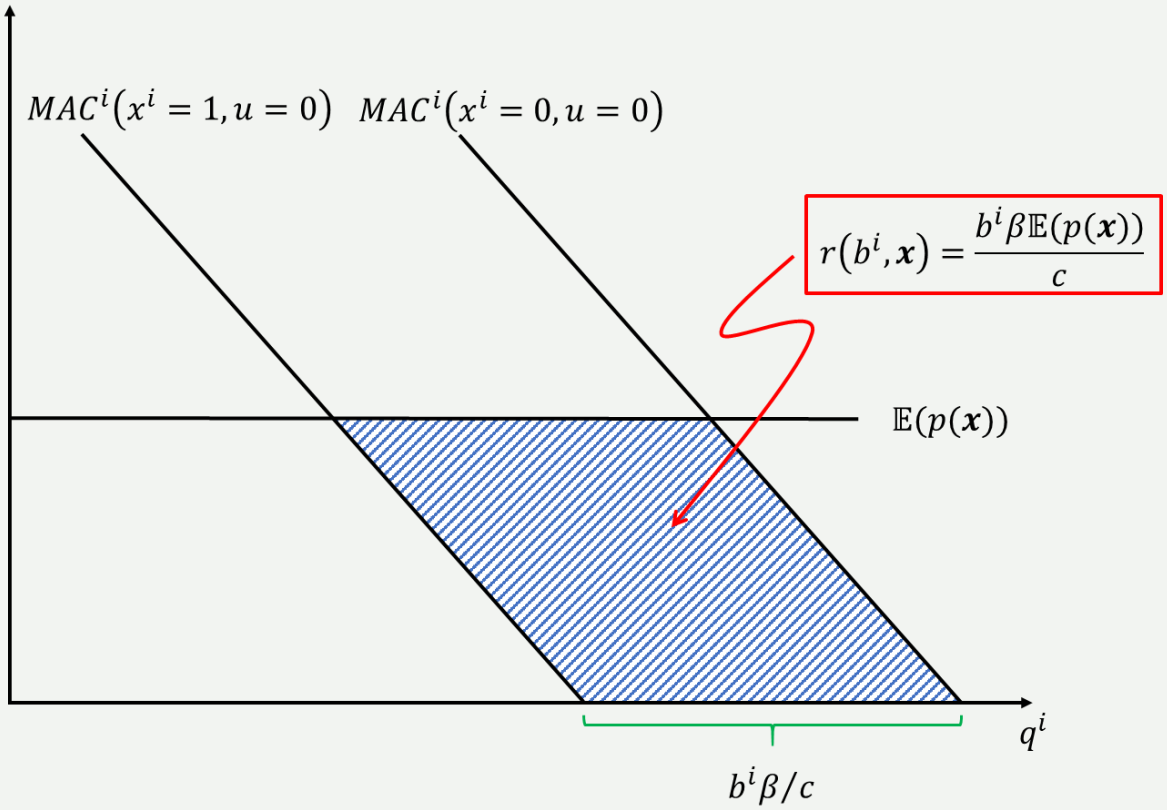
Theoretical Model: Technology Choice (0)

$\boldsymbol{x} = (x^1, \ldots, x^n)$ — vector of firms' technology choices

$\mathbb{E}(p(\boldsymbol{x}))$ — expected permit price given technology choices

Firm's expected reduction in compliance costs with investment

$$r(b^i, \boldsymbol{x}) = \frac{b^i \beta \mathbb{E}(p(\boldsymbol{x}))}{c}$$



Theoretical Model: Technology Choice (1)

A firm's expected reduction in compliance costs with investment

$$r(b^i, \boldsymbol{x}) = \frac{b^i \beta \mathbb{E}(p(\boldsymbol{x}))}{c}$$

f — fixed cost of investment

Firm's investment choice

$$x^i = \begin{cases} 0 \text{ if } f > r(b^i, \boldsymbol{x}) \\ 1 \text{ if } f < r(b^i, \boldsymbol{x}) \end{cases}$$

Result: Since $r(b^i, x)$ is increasing in b^i, in an equilibrium with investors and non-investors, only high-cost firms invest

Technology Choice with and without Price Floor

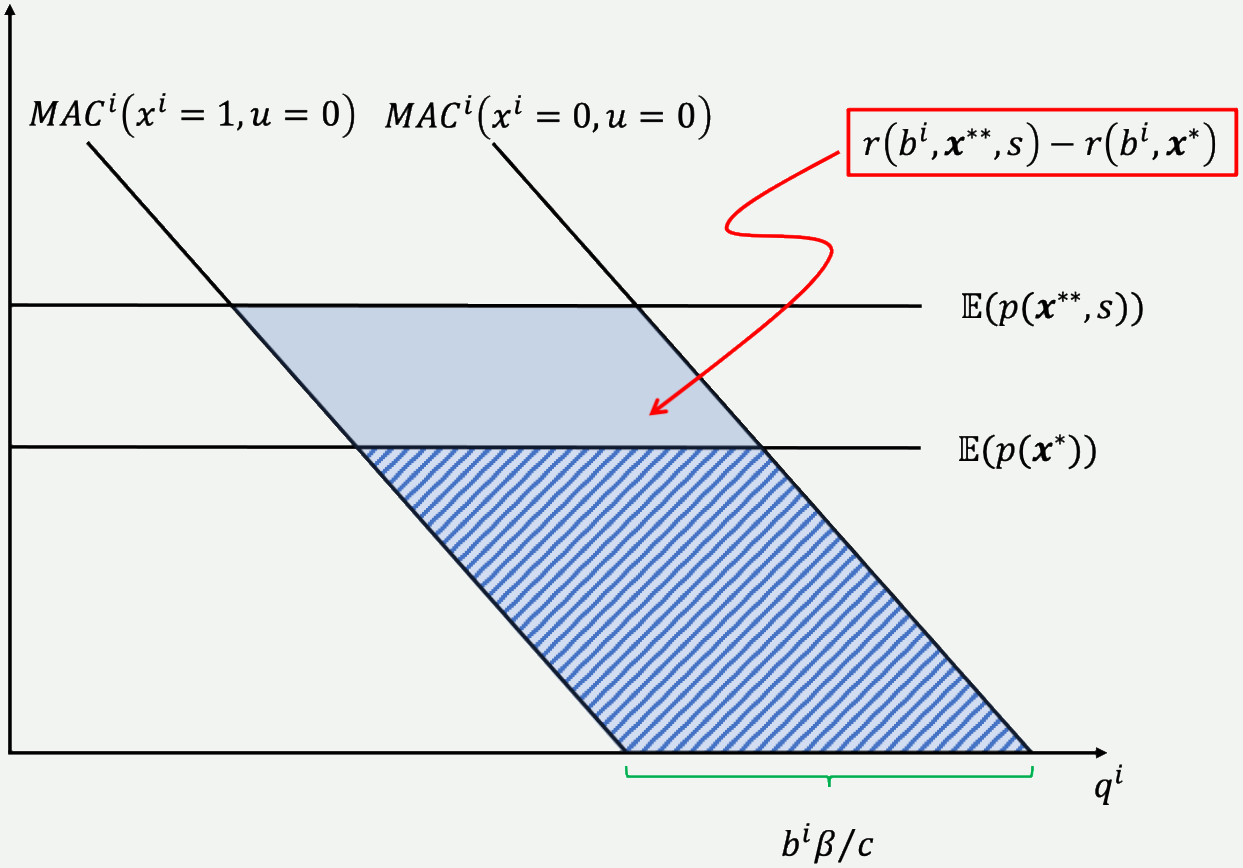
Let $\boldsymbol{x}^*(\boldsymbol{x}^{**})$ be equilibrium investments without (with) a **hard** price floor, s

Then

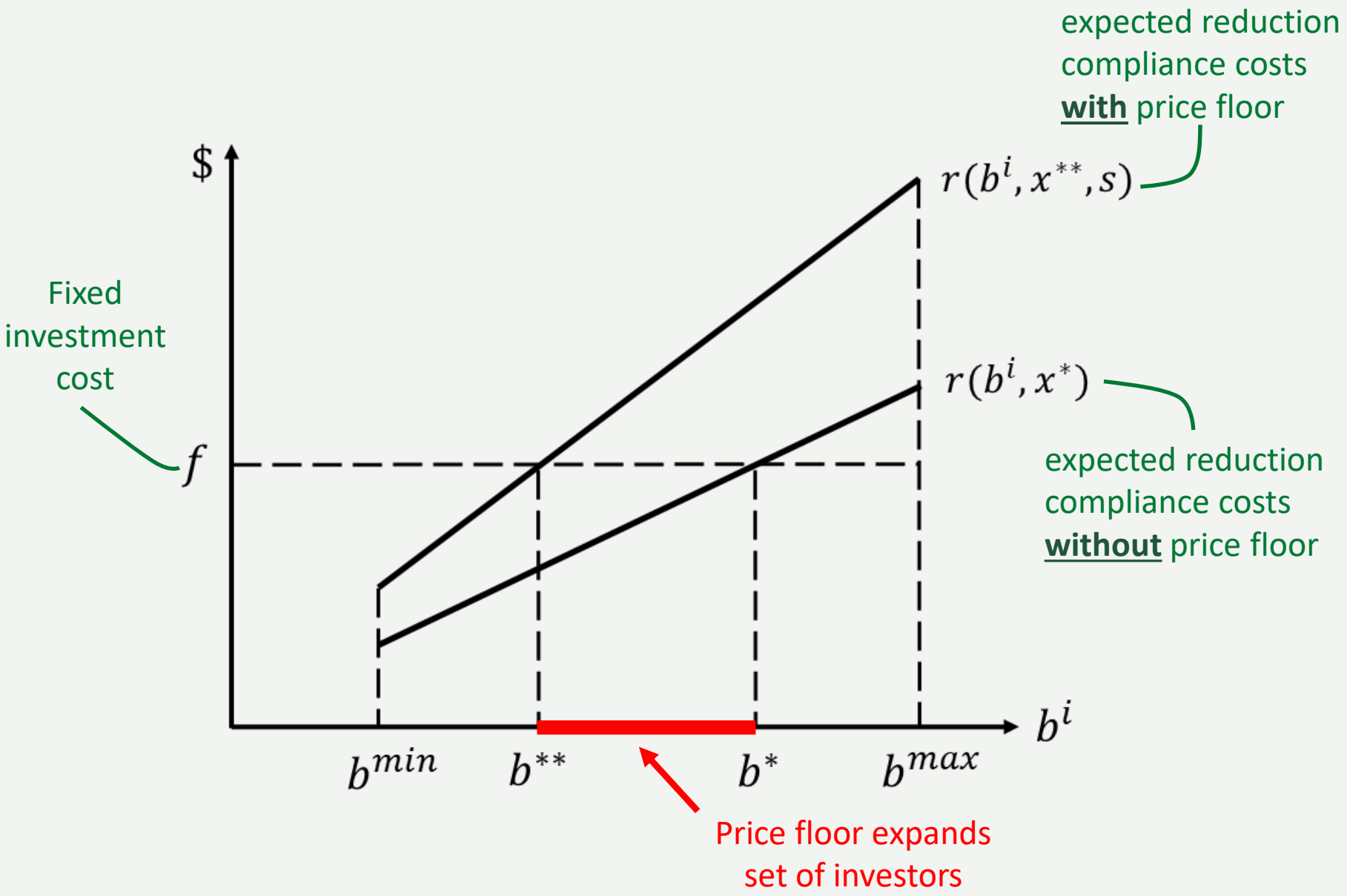
$$\mathbb{E}\big(p(\boldsymbol{x}^*)\big) < \mathbb{E}(p(\boldsymbol{x}^{**}, s))$$

and

$$r\big(b^i, \boldsymbol{x}^*\big) < r\big(b^i, \boldsymbol{x}^{**}, s\big)$$



Impact of Price Floor on Firms' Investment



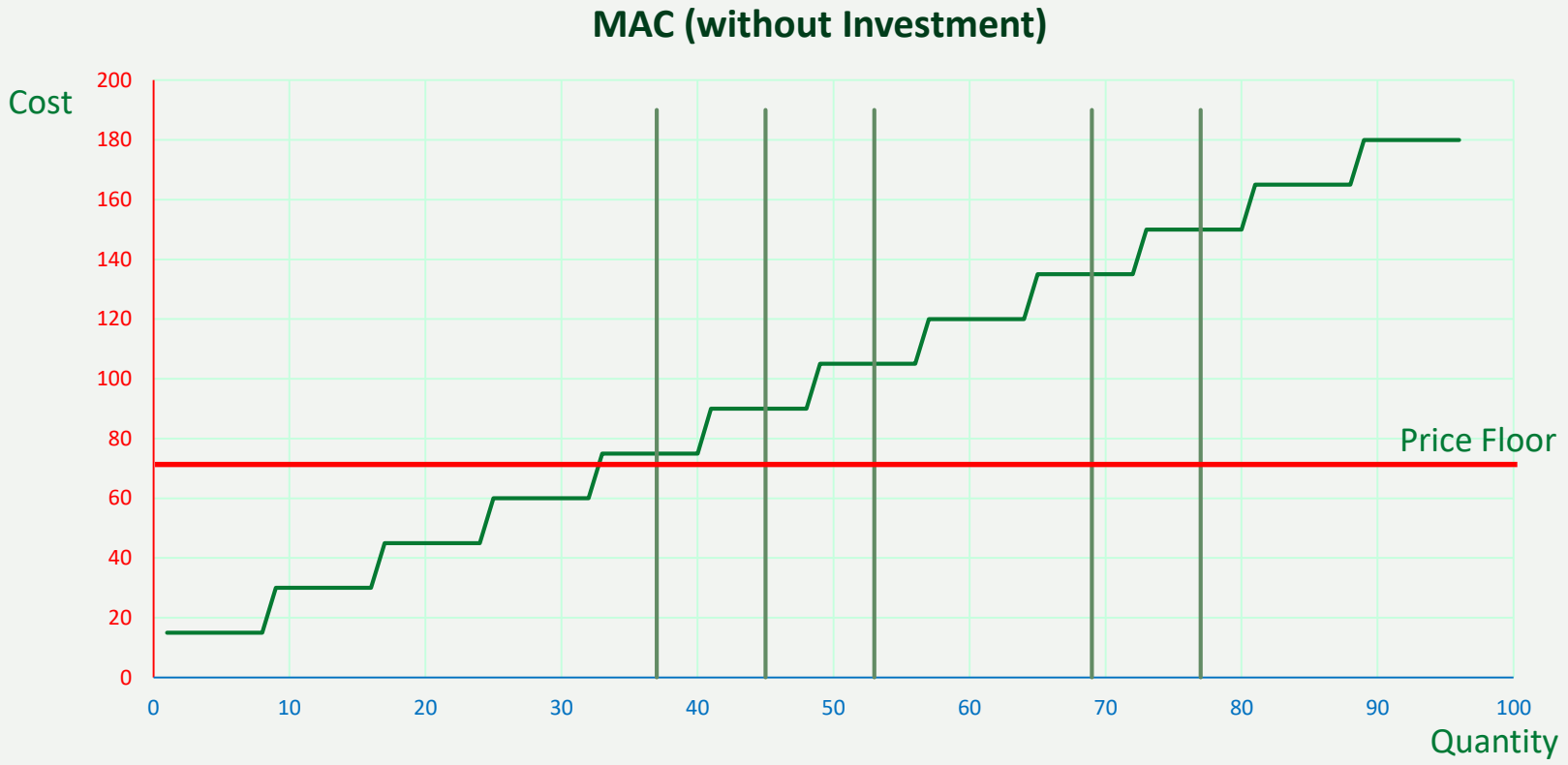
Experimental Design and Data

- Treatment variable: price floor
- Baseline (no-control): market without a price floor
- Each market consisted of 8 heterogeneous firms (traders) where firm heterogeneity (b^i) can take on values 100, 200, …, 800
- Discretized quantity of emissions (q)
- Abatement cost shock (u) can take value from {-40, -20, 0, 20, 40} with equal probability
- Fixed discrete shift of abatement cost ($\beta = 0.252$) due to investment, with investment being a dichotomous choice {0, 1}
- Fixed investment cost ($f = 200$)

Experimental Design and Data

- Data were collected from a total of **11 markets** (all comprising 8 traders)
  - ✓ No-control baseline: 5 markets
  - ✓ Price floor treatment: 6 markets
- **Double auction market institution** where traders make investment and permit trading decisions across **16 periods** (trader type being fixed)
- A total of **184 emissions permits distributed equally across 8 traders** (i.e., each trader holds 23 permits initially) at start of each period
- New random draws of random variable u at start of each period
- In price floor treatment, no offers or transactions were allowed at prices below the price floor (i.e., excess permit supply when floor is binding)

Marginal Abatement Costs



Vertical lines correspond to 5 abatement cost shocks affecting amount of required abatement; horizontal line indicates price floor of 70

Hypotheses

1. **(Investment):** In a competitive permit market,

a) A price floor increases the number of firms investing in abatement technology

b) Change in investment frequency is greatest for "intermediate abatement cost" firms

2. **(Prices):** Emission permit prices are

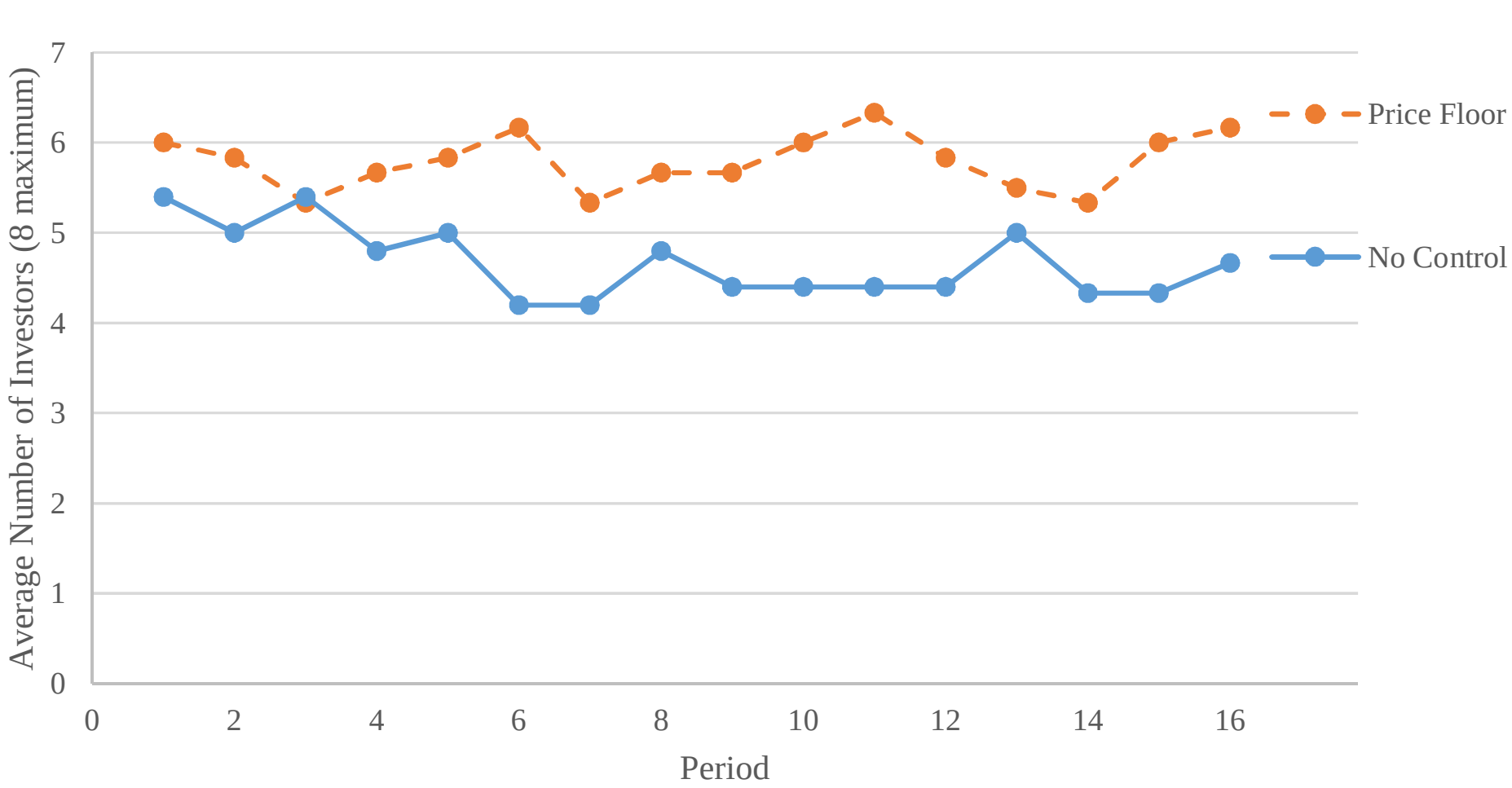
a) Lower on average without the price floor

b) Lower in periods with favorable shocks that lower abatement costs

c) Lower in periods in which greater number of firms invest in abatement technology

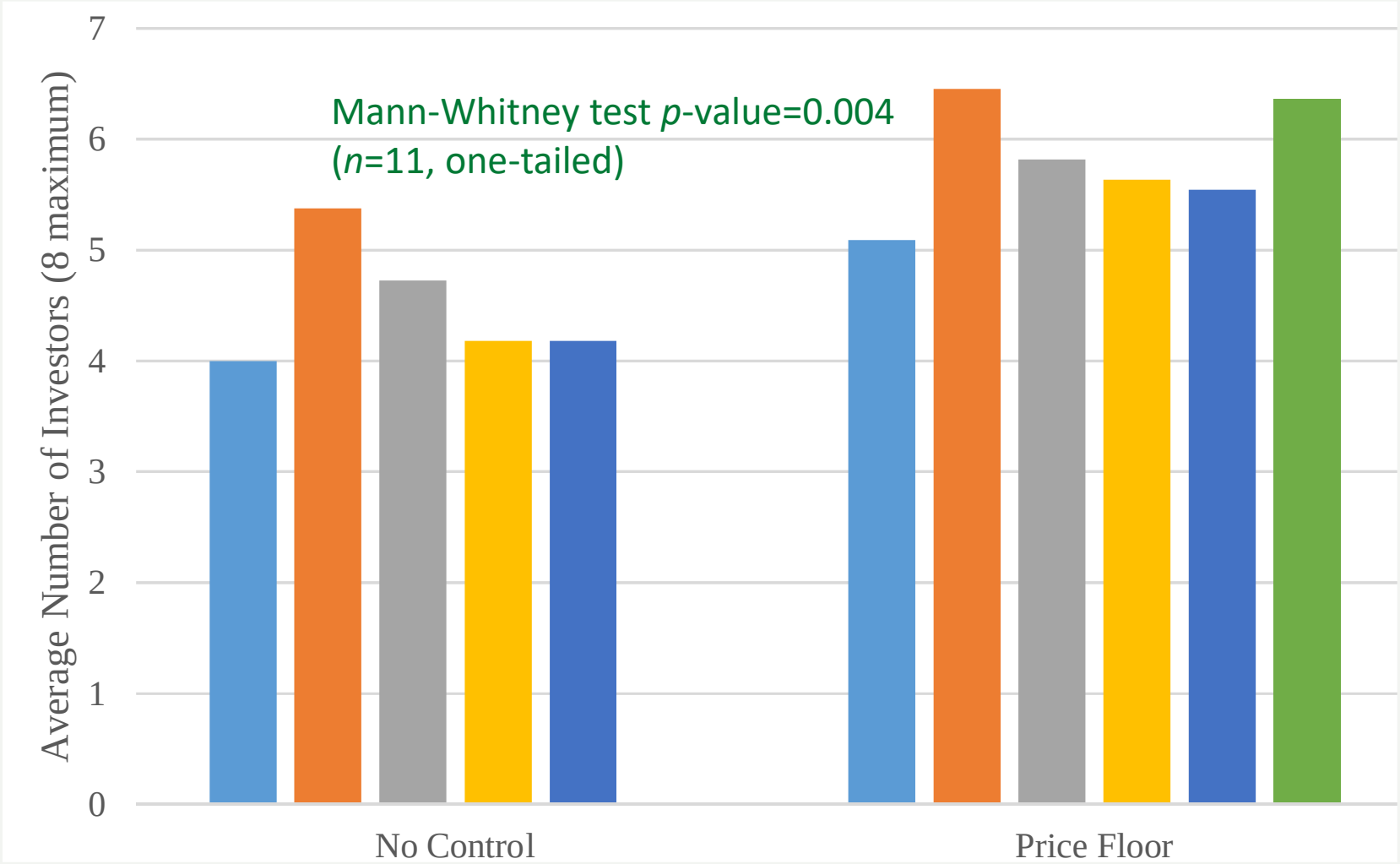
Results: Cost-Reducing Investment (0)

Mean Number of Investing Firms, by Period (pooled over 11 markets)



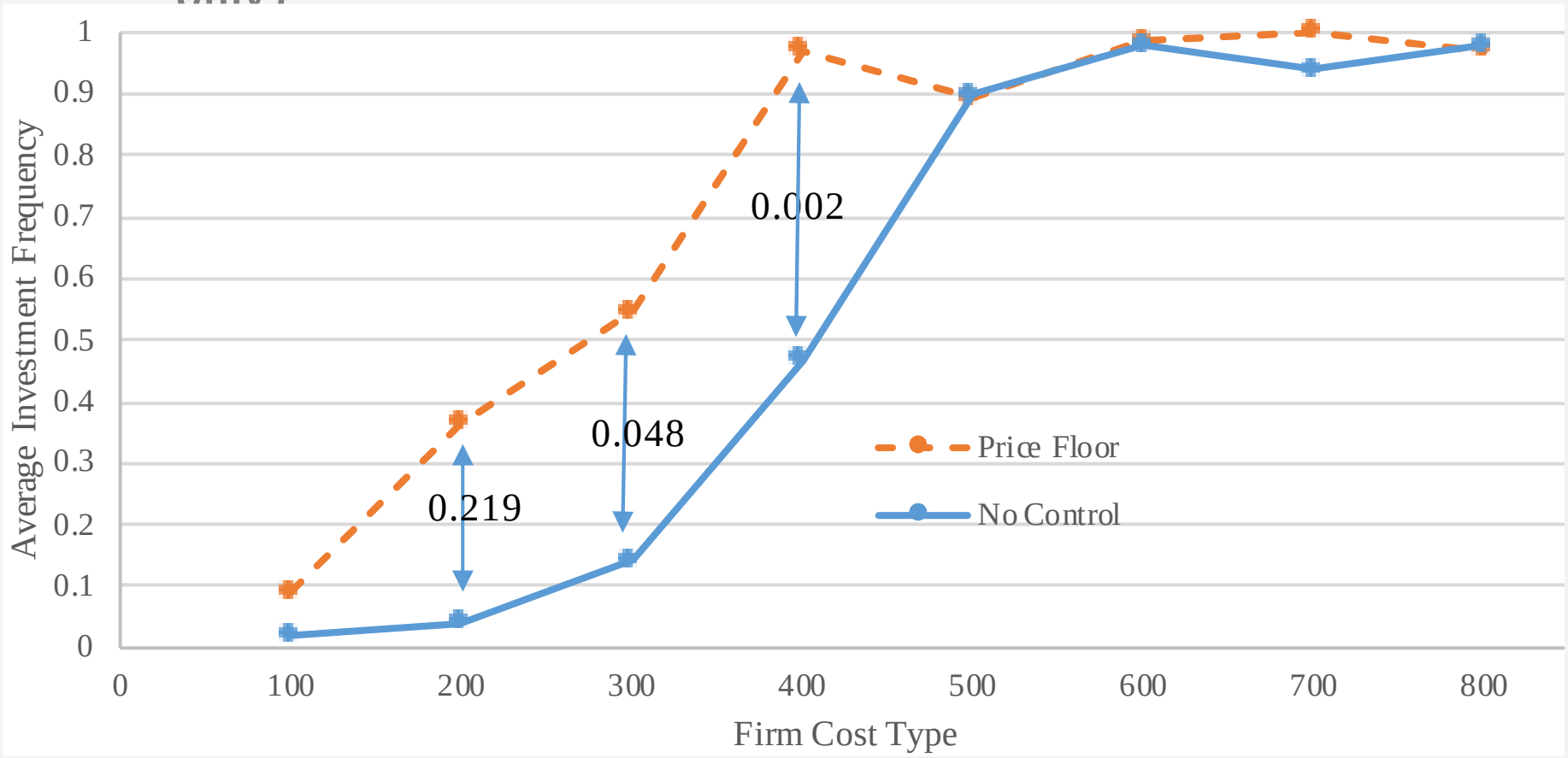
Results: Cost-Reducing Investment (1)

Mean Number of Investing Firms, by **Market** (periods 6-16 only)



Results: Cost-Reducing Investment (2)

Mean Investment Rate, across Firm Types (periods 6-16 only)



P-values shown for firm types $b^i = 200, 300, 400$

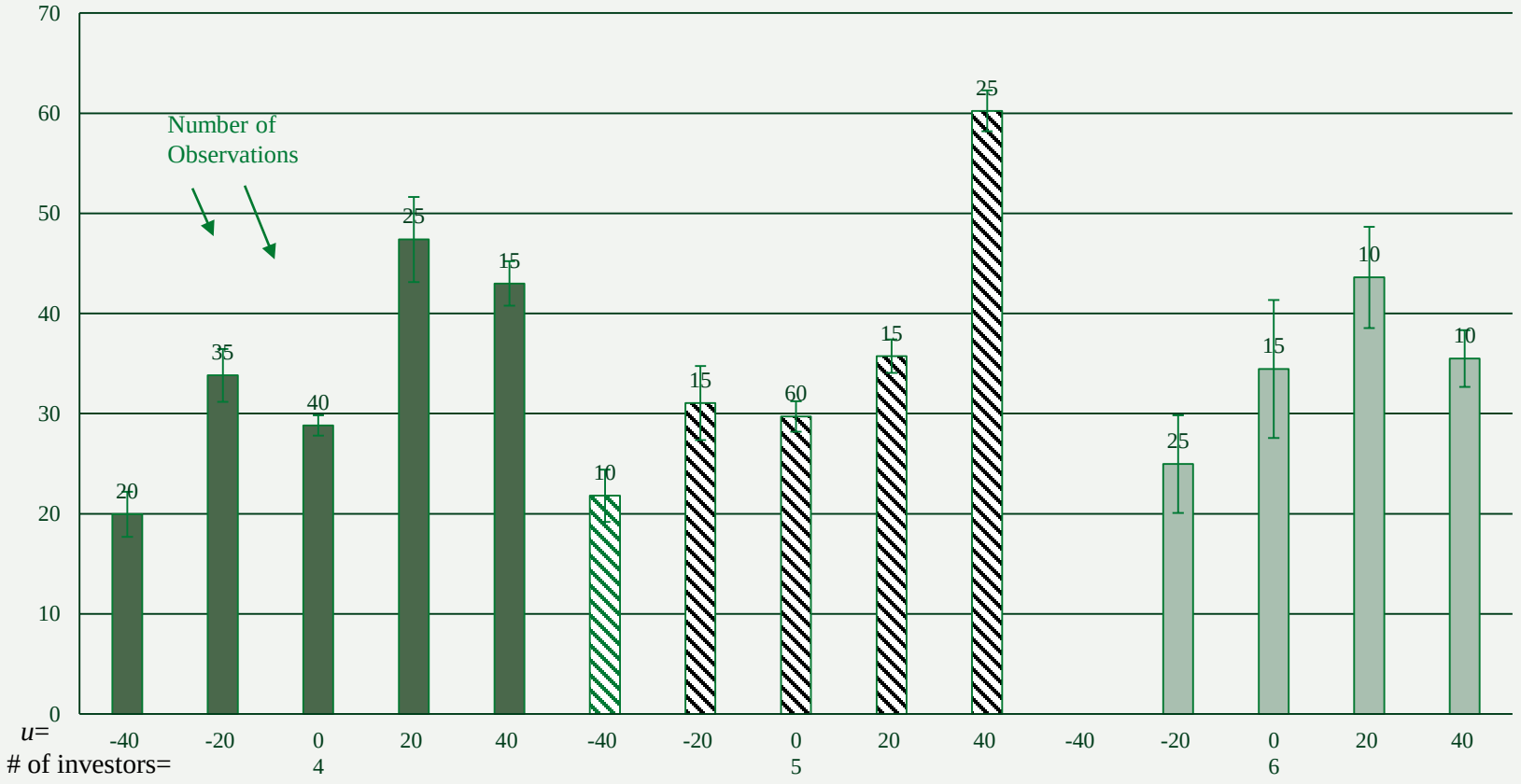
Results: Permit Prices (0)

Table 1: Equilibrium Permit Prices by Abatement Cost Shock and Number of Investors

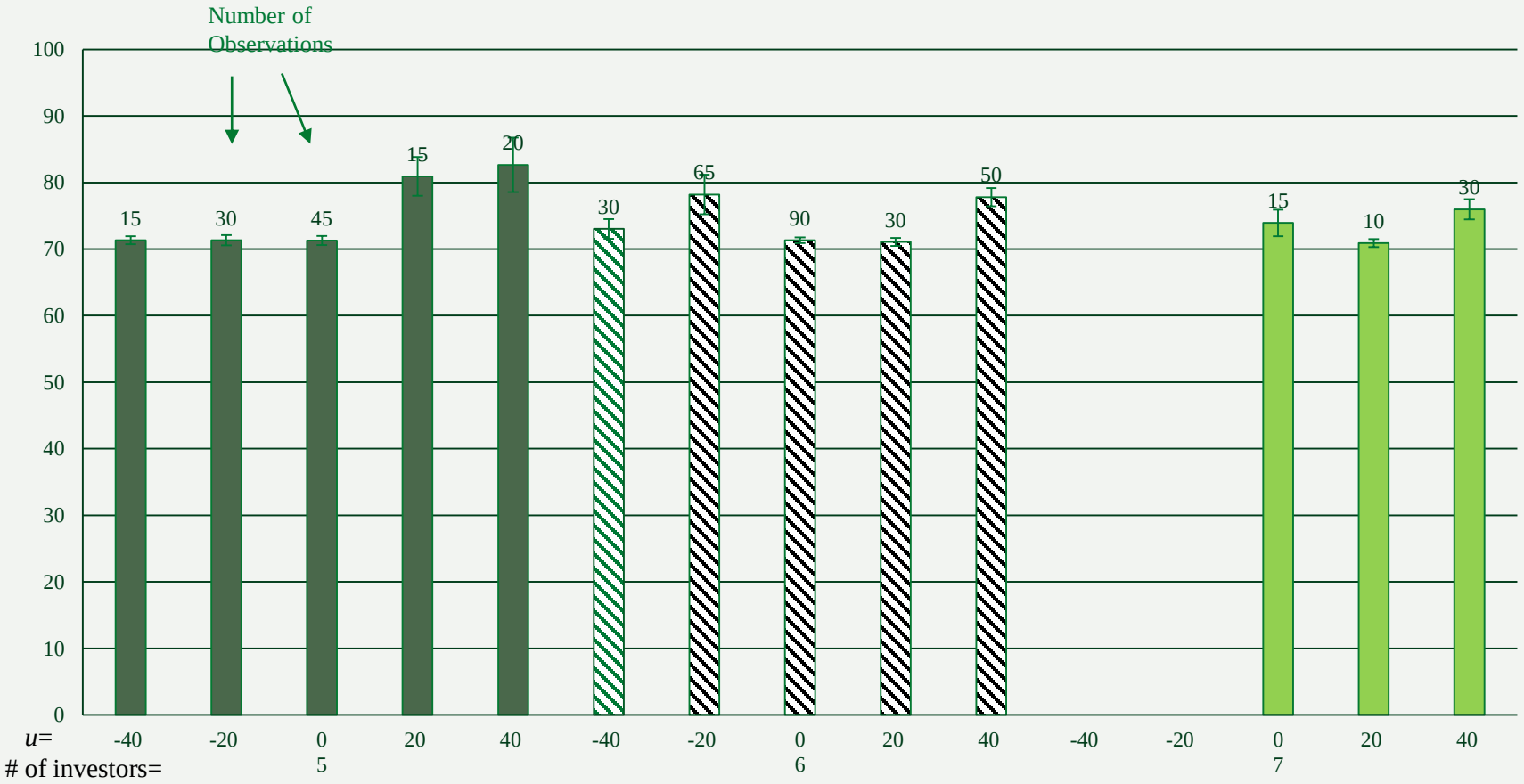
	Abatement Cost Shock (u)				
(#) Investors	-40	-20	0	20	40
(0) None	75	90	105	135	150
(1) $b^i = 800$	45	60	75	105	120
(2) $b^i = 800, 700$	30	45	60	90	105
(3) $b^i = 800, 700, 600$	15	30	45	75	90
(4) $b^i = 800, 700, 600, 500$	0	15	30	60	75
(5) $b^i = 800, 700, 600, 500, 400$	0	0	15	45	60
(6) $b^i = 800, 700, 600, 500, 400, 300$	0	0	0	30	45
(7) $b^i = 800, 700, 600, 500, 400, 300, 200$	0	0	0	30	45
(8) $b^i = 800, 700, 600, 500, 400, 300, 200, 100$	0	0	0	30	45

Prices are predicted to be lower with favorable cost shocks and when more firms invest in abatement cost reductions

Results: Permit Prices (1)
No Price Control (Mean Prices, final 5 trades each period)



Results: Permit Prices (2)
With Price Floor (Mean Prices, final 5 trades each period)



Results: Permit Prices (3)

Mean Price in:	No Price Control		Price Floor Treatment	
	Final 5 Transactions	Final 3 Transactions	Final 5 Transactions	Final 3 Transactions
	(1)	(2)	(3)	(4)
Cost Shock (-40 to 40)	0.38**	0.41**	0.04**	0.04**
	(0.07)	(0.07)	(0.01)	(0.02)
Number of Investors (0 to 8)	-3.29*	-3.86*	-0.70	-0.34
	(2.02)	(2.05)	(0.52)	(0.57)
Period Number (6 to 16)	-0.15	-0.11	-0.09	-0.10
	(0.53)	(0.53)	(0.10)	(0.11)
Constant	48.64**	50.52**	76.77**	74.76**
	(10.19)	(10.27)	(3.33)	(3.62)
R-squared	0.430	0.477	0.051	0.074
Observations	49	49	66	66

Price responsiveness to investment and cost shock occurs only without the price floor

Summary and Main Lesson

- This paper develops a theoretical model and implements a laboratory experiment to examine the impact of the introduction of a hard price floor in emissions trading markets on the incentives to invest in cost-reducing abatement technology

- Consistent with the theoretical prediction, the experimental results confirm that a price floor is conducive to enhancing investment incentives. In particular, in a heterogeneous market featuring investors and non-investors, a price floor expands the number of investors

- Prices are responsive to investment (and abatement cost shocks) only when the price floor is not implemented