Commitment Timing to Environmental Policy and the Adoption of Low-Pollution Technologies: An Experiment

by
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Introduction

- Price based environmental policy instruments do not only lead to **static efficiency** of abatement efforts,
- but also provide **dynamic incentives** to develop and **adopt advanced abatement technologies**
- However, incentives through price vs. quantity instruments may differ.
- But commitment and ratcheting of policy is important!

Related Literature

The theoretical basis of the paper is:

- Requate & Unold 2001 JITE, 2003 EER

Related also:

- Requate 2005,
- Perino & Requate 2012, JEEM
- See also Moner-Coloques & Rubio 2016

Exerimental design based on:

- Camacho, Requate, Waichman, ERE 2012

Theoretical background

- *N* firms have some conventional abatement technology with downward sloping marginal abatement cost curves (MACs)
- A new abatement technology is available, inducing lower MACs.
- Adopting the new technology firms incur a fixed cost *F*.
- Marginal damage is increasing.

Theoretical background

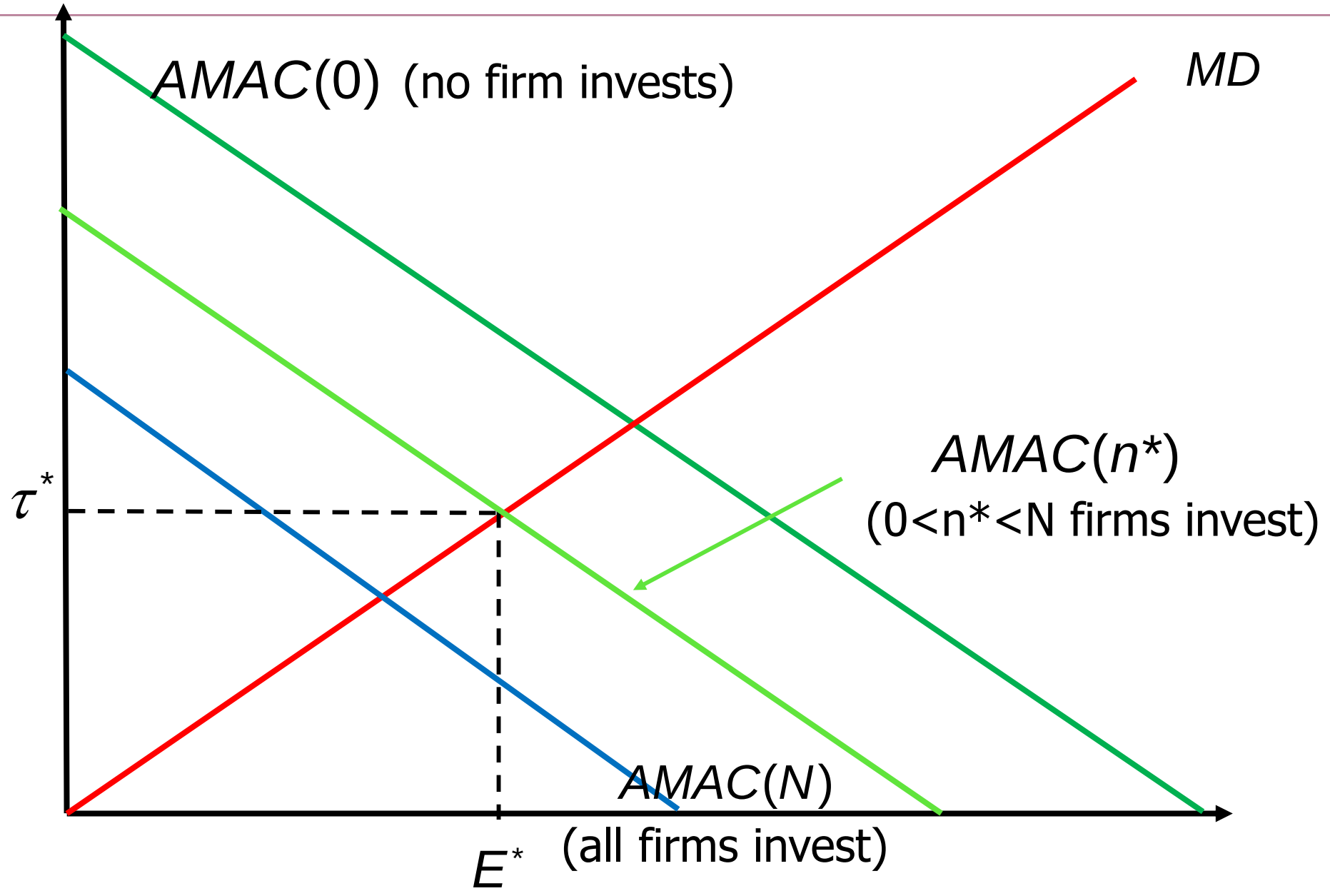
In a social optimum:

- no firm should adopt, if the investment cost *F* sufficiently high.
- All firms should adopt, if the investment cost *F* sufficiently low.
- Some but not all firms should adopt for intermediate values of *F !*
- *In our experiment this is the case!*

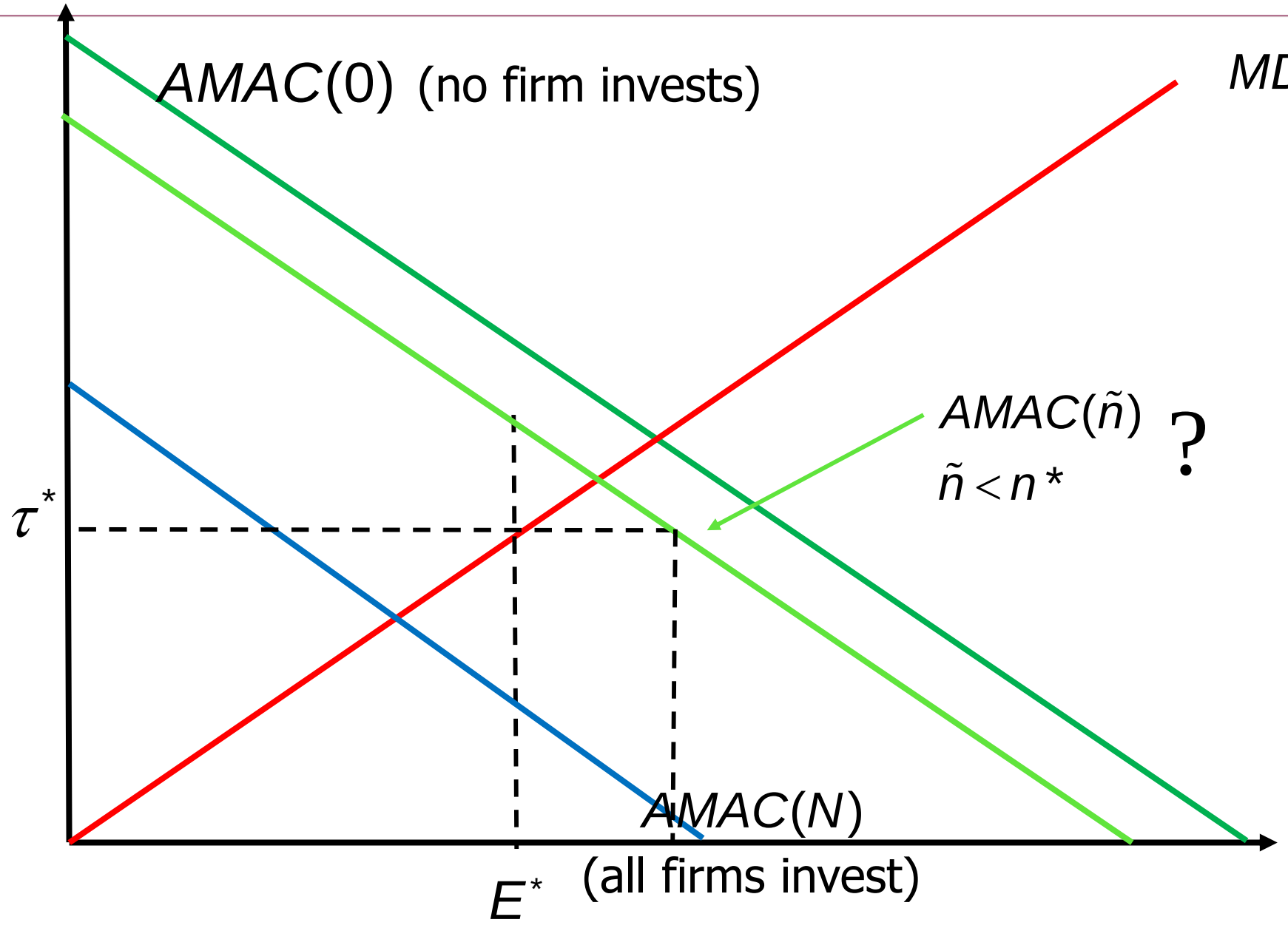
Theoretical background

- First-best investment can be decentralized by four different scenarios:
  - an ex ante optimal tax (before investment)
  - an ex post optimal tax (set after observing investment)
  - an ex ante optimal permit policy (before investment)
  - an ex post optimal permit policy (set after observing investment)

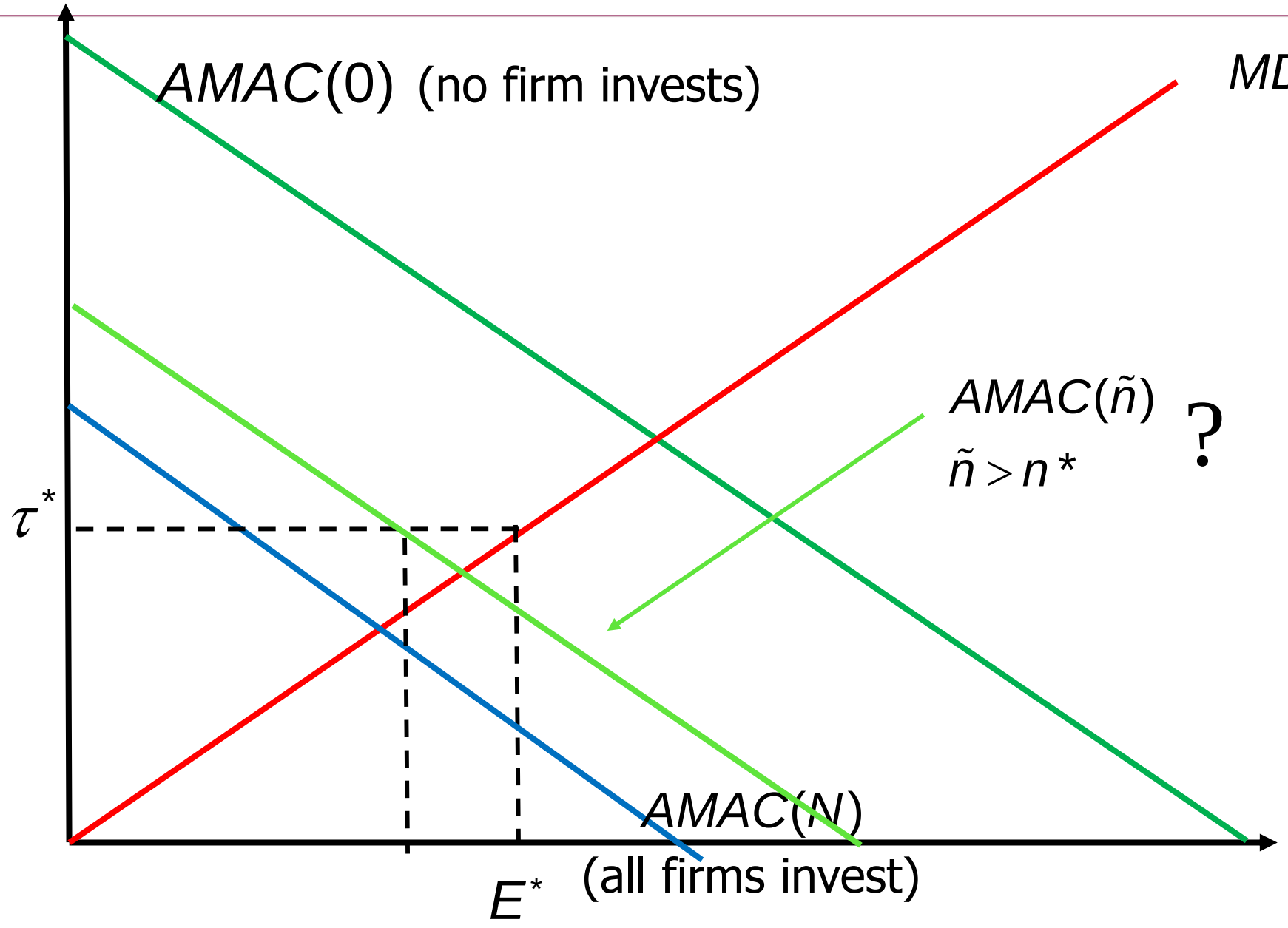
Ex ante policies



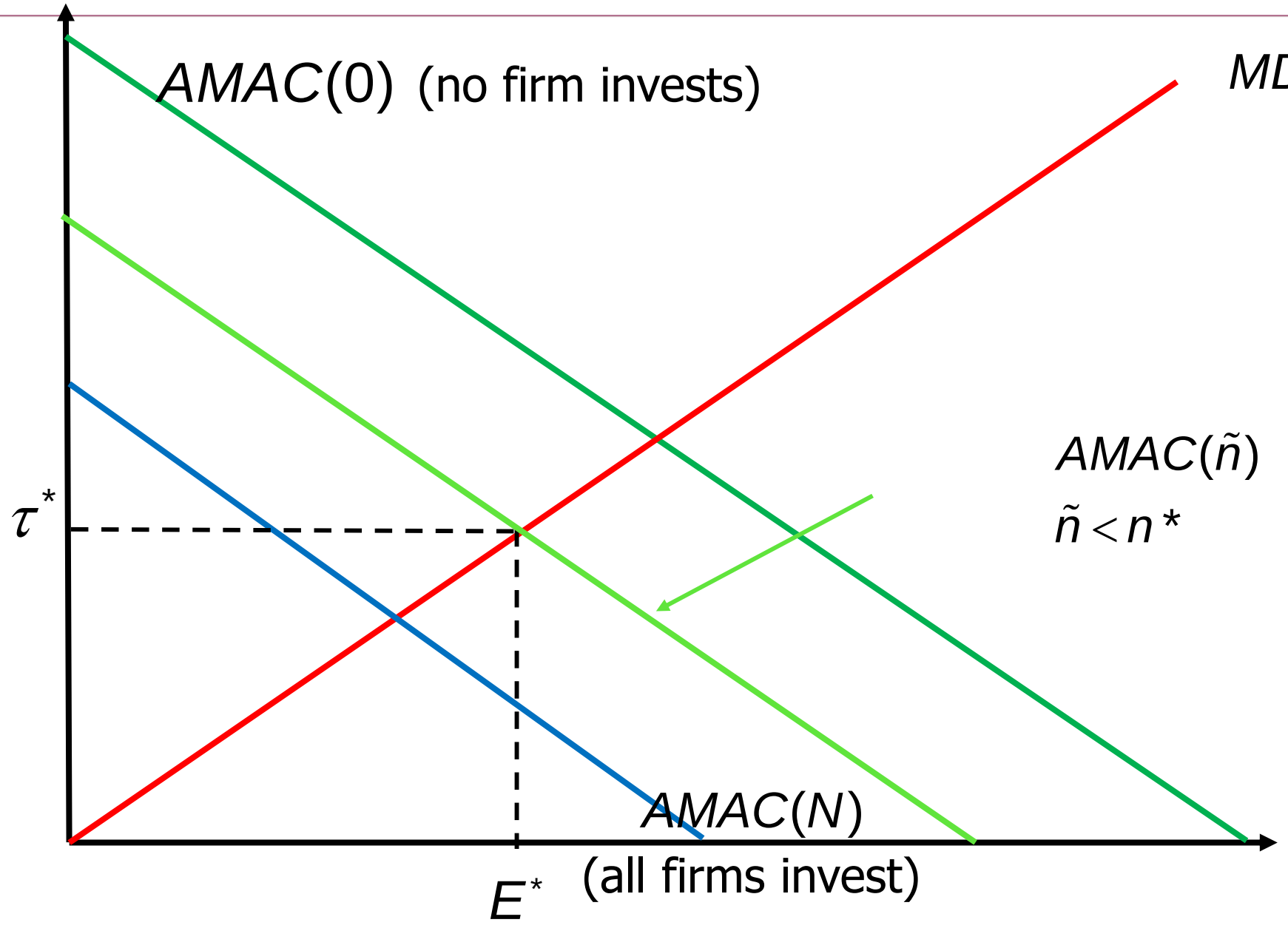
Ex ante policies: case of underinvestment



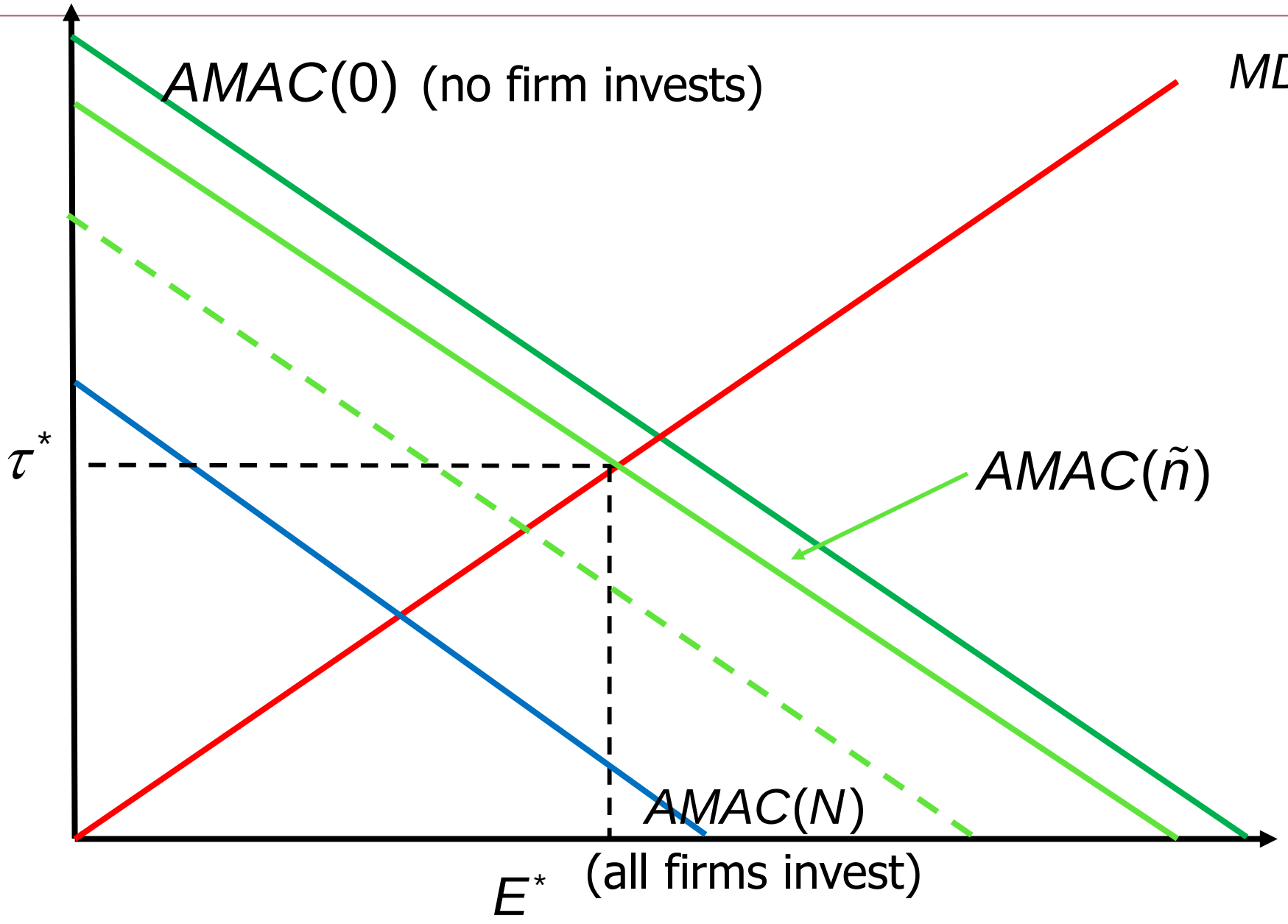
Ex ante policies: case of overinvestment



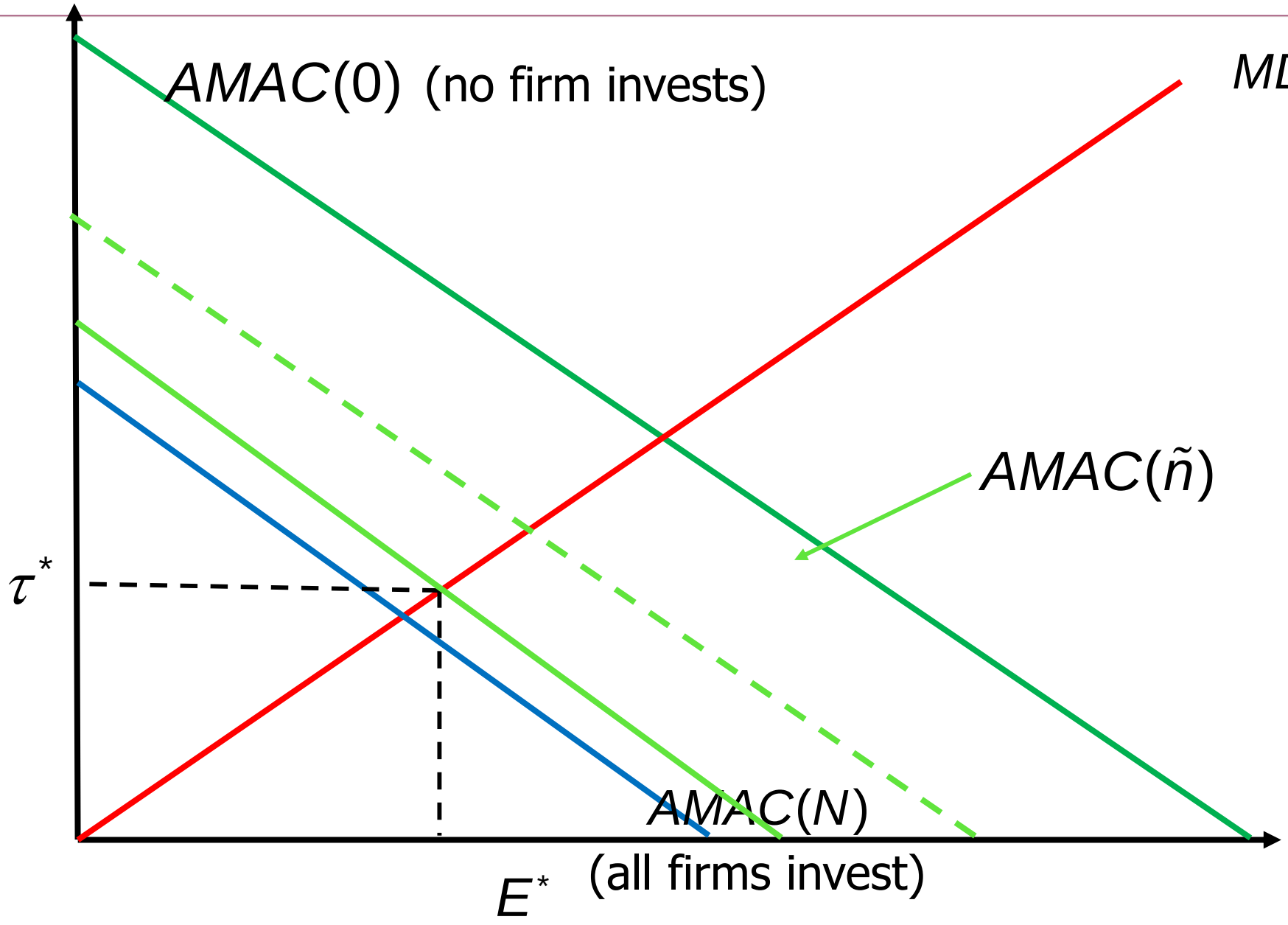
Ex post policies



Ex post policy with underinvestment



Ex post policy with overinvestment



Research hypothesis

H: The four different policies are equivalent and efficient!

- In other words:
  - If the tax (permit) policy is set **ex ante**, the optimal investment pattern will occur.
  - If the tax (permit) policy is set **ex post**, firms anticipate the optimal policy response and the optimal investment pattern will also occur.

Experimental Design

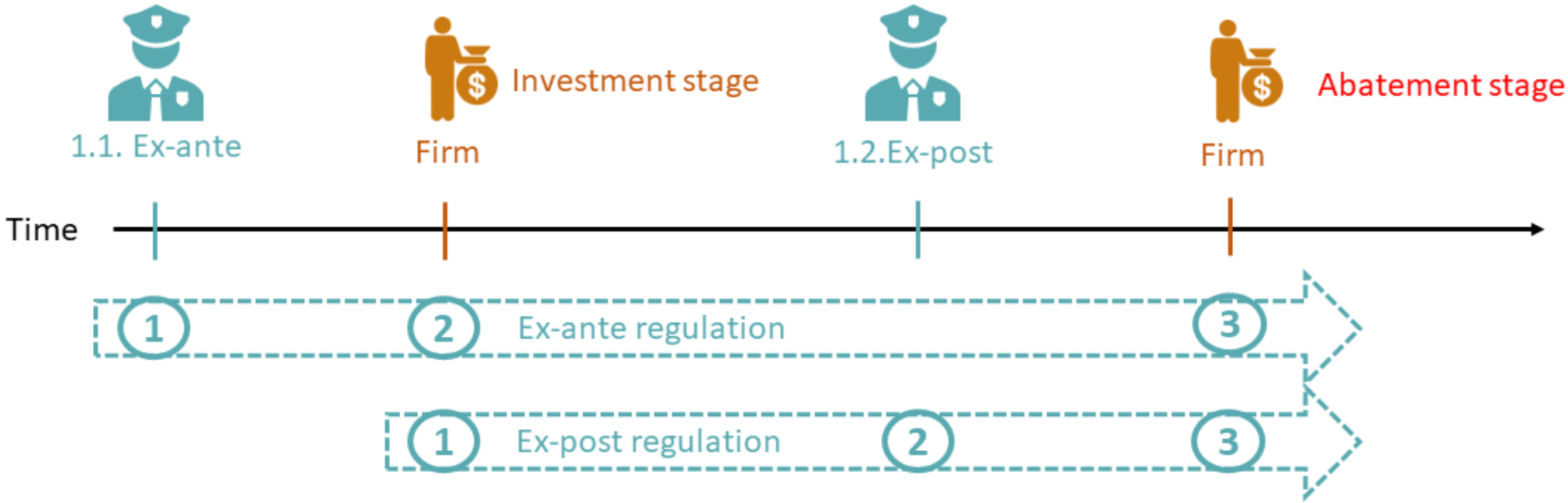
- Industry consist of 10 firms (subjects).
- 5 different initial technologies are assigned among the 10 firms.
  (i.e. always 2 firms have the same technology)
- In social optimum the 4 firms with the 2 highest MAC curves should invest, the others should not!

Table 1: Marginal Abatement Cost (MAC) per technology type. $T_1, ..., T_5$ denote the initial technologies, while a denotes the advanced abatement technology

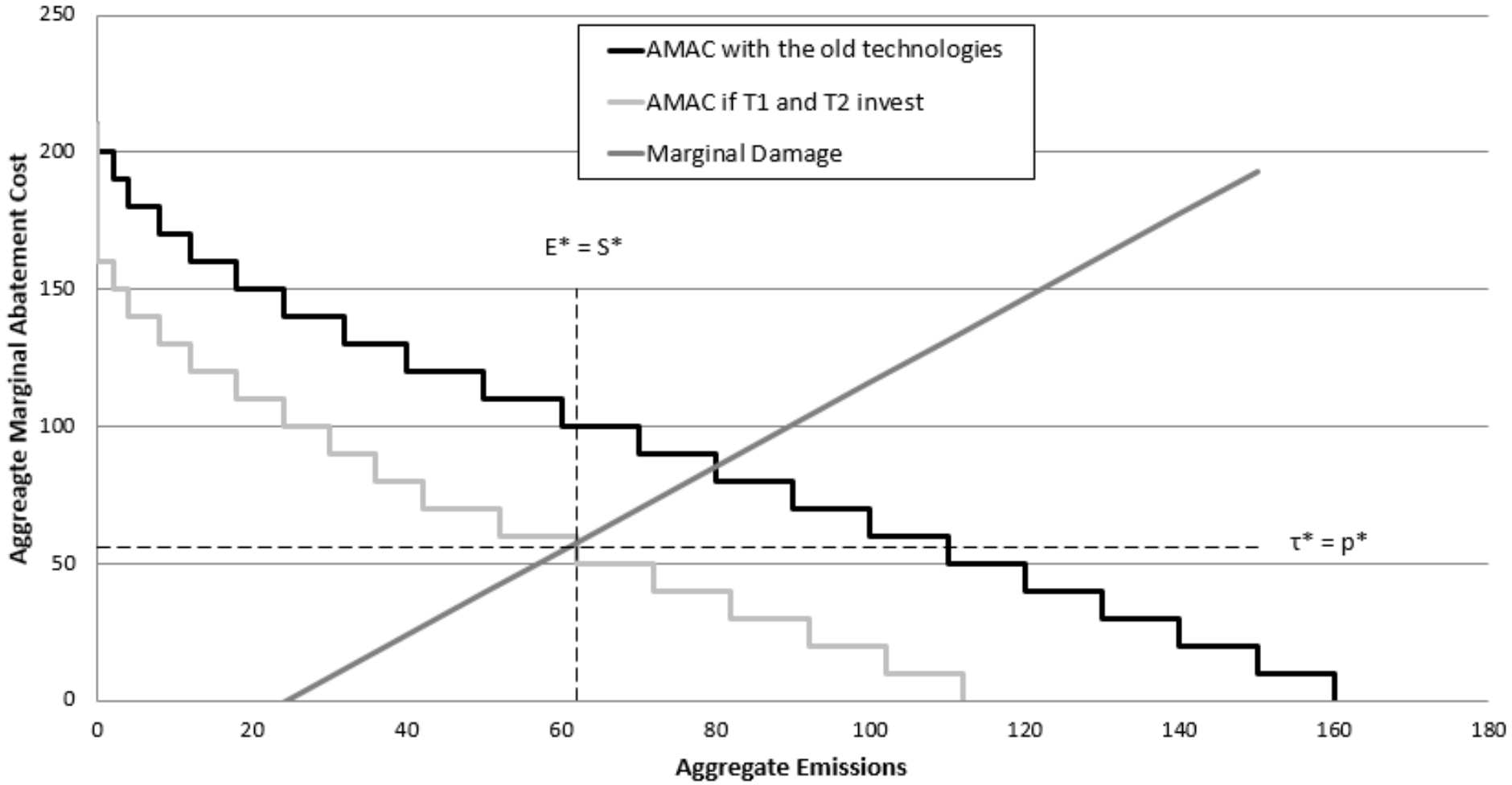
Emissions per technology type						MAC
T_1	T_2	T_3	T_4	T_5	a	
20	18	16	14	12	7	0
19	17	15	13	11	6	10
18	16	14	12	10	5	20
17	15	13	11	9	4	30
16	14	12	10	8	3	40
15	13	11	9	7	2	50
14	12	10	8	6	1	60
13	11	9	7	5	0	70
12	10	8	6	4		80
11	9	7	5	3		90
10	8	6	4	2		100
9	7	5	3	1		110
8	6	4	2	0		120
7	5	3	1			130
6	4	2	0			140
5	3	1				150
4	2	0				160
3	1					170
2	0					180
1						190
0						200

Experimental Design: order of moves

Treatment factor 1: Timing of regulation policy (1.1 ex-ante vs. 1.2 ex-post)
Treatment factor 2: Regulation policy instrument (2.1 tax vs. 2.2 permits)



Aggregate MACs with no and optimal investment



The treatments

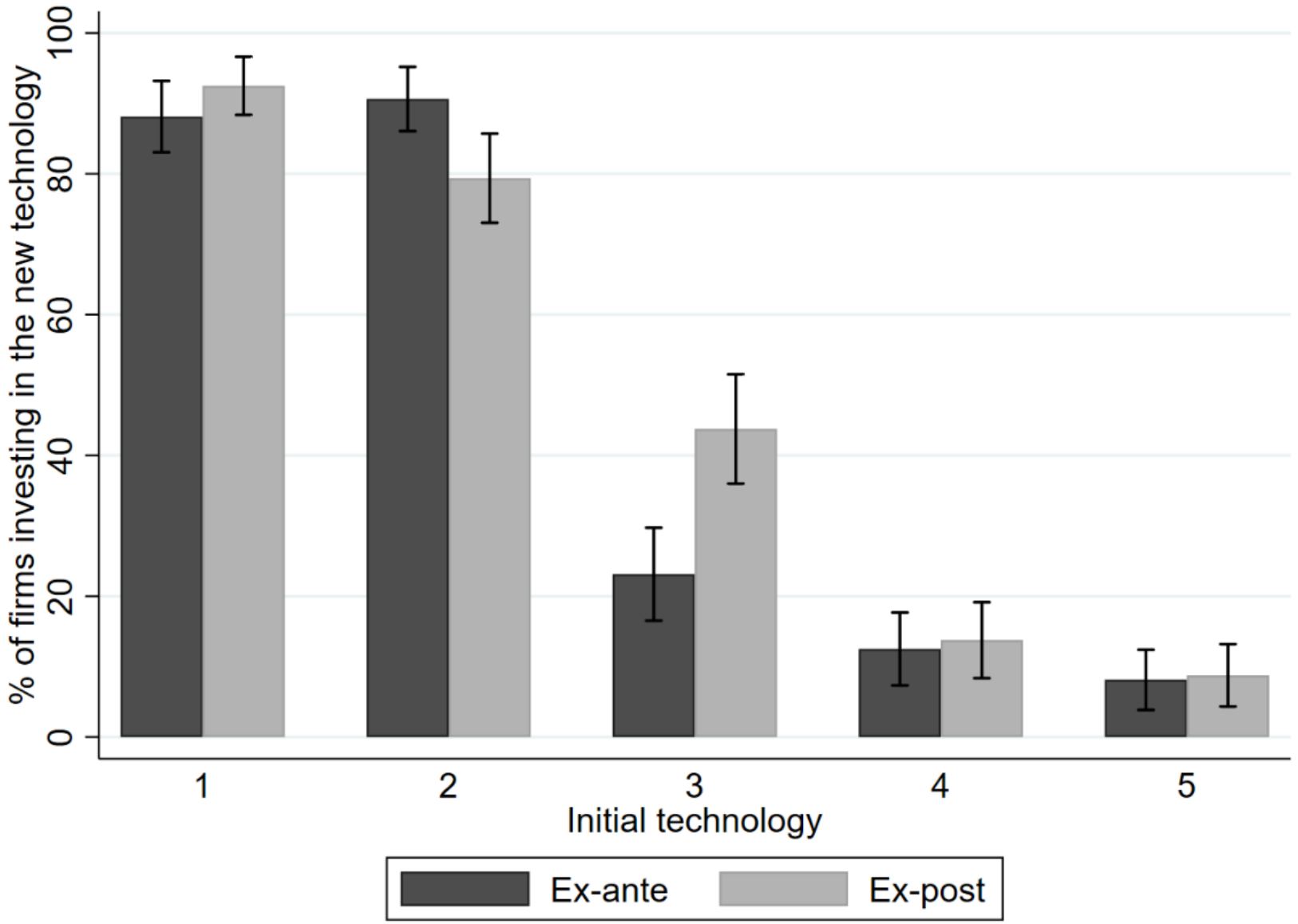
Table 2: Experimental treatments and parameters

Treatment	Timing	Policy	Policy-level (τ)	Policy-level (S)	Groups	Participants (lab + online)
Ex-ante Tax	ex-ante	tax	56	-	8	40 + 40
Ex-post Tax	ex-post	tax	$f(I)$	-	8	40 + 40
Ex-ante Permits	ex-ante	permit	-	62	8	40 + 40
Ex-post Permits	ex-post	permit	-	$f(I)$	8	40 + 40
					32	320

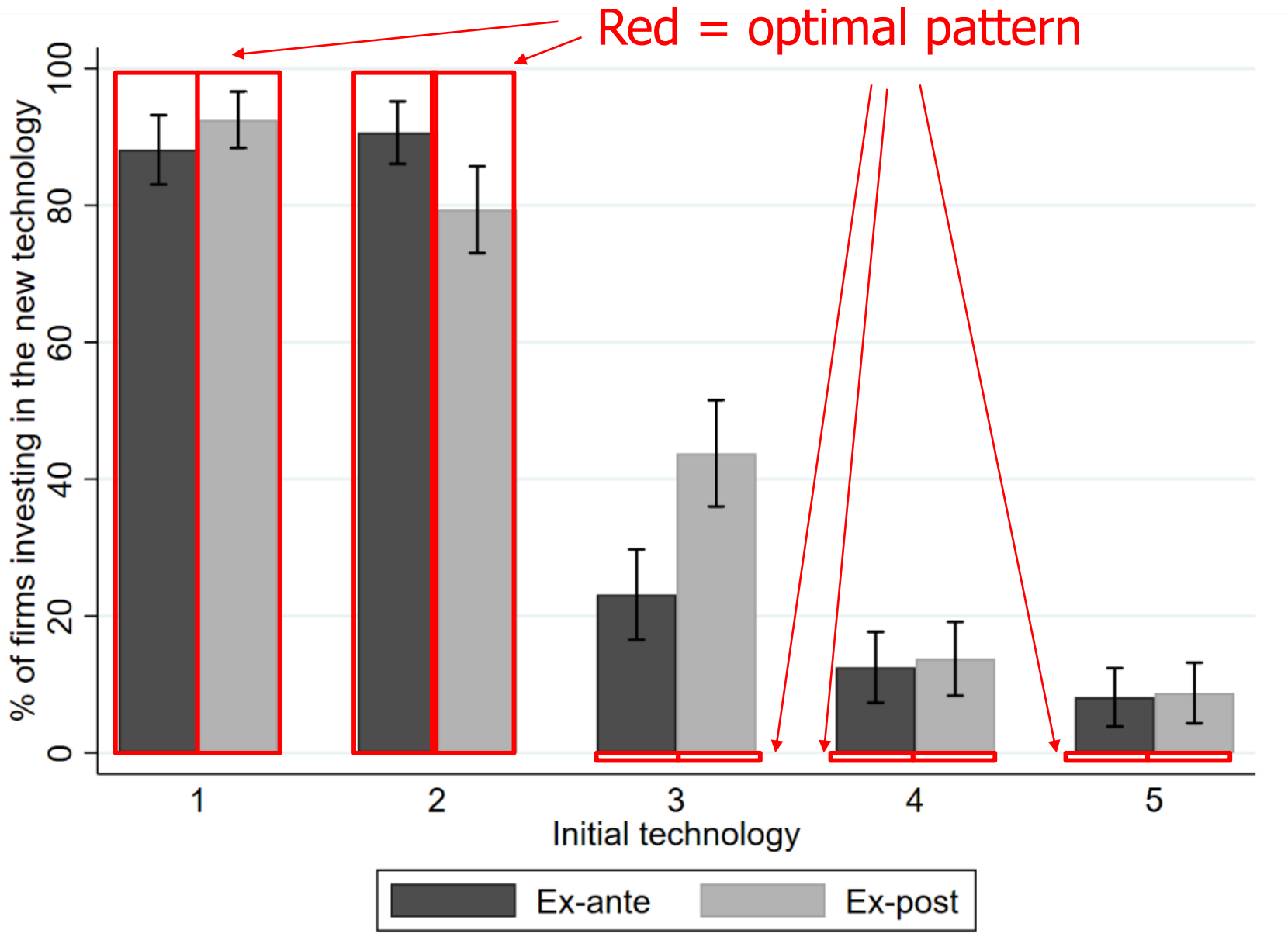
A total of 320 students (160 in the lab (offline) and 160 online) participated in the experiment. $f(I)$ indicates that the tax rate (τ) and the number of permits (S) are determined in the ex-post treatments according to the current technology profile in the industry after the firms made their investment decisions. "Groups" are number of independent markets per treatment.

Results

Investment patterns under tax treatments



Investment patterns under tax treatments



Investment patterns under permit treatments

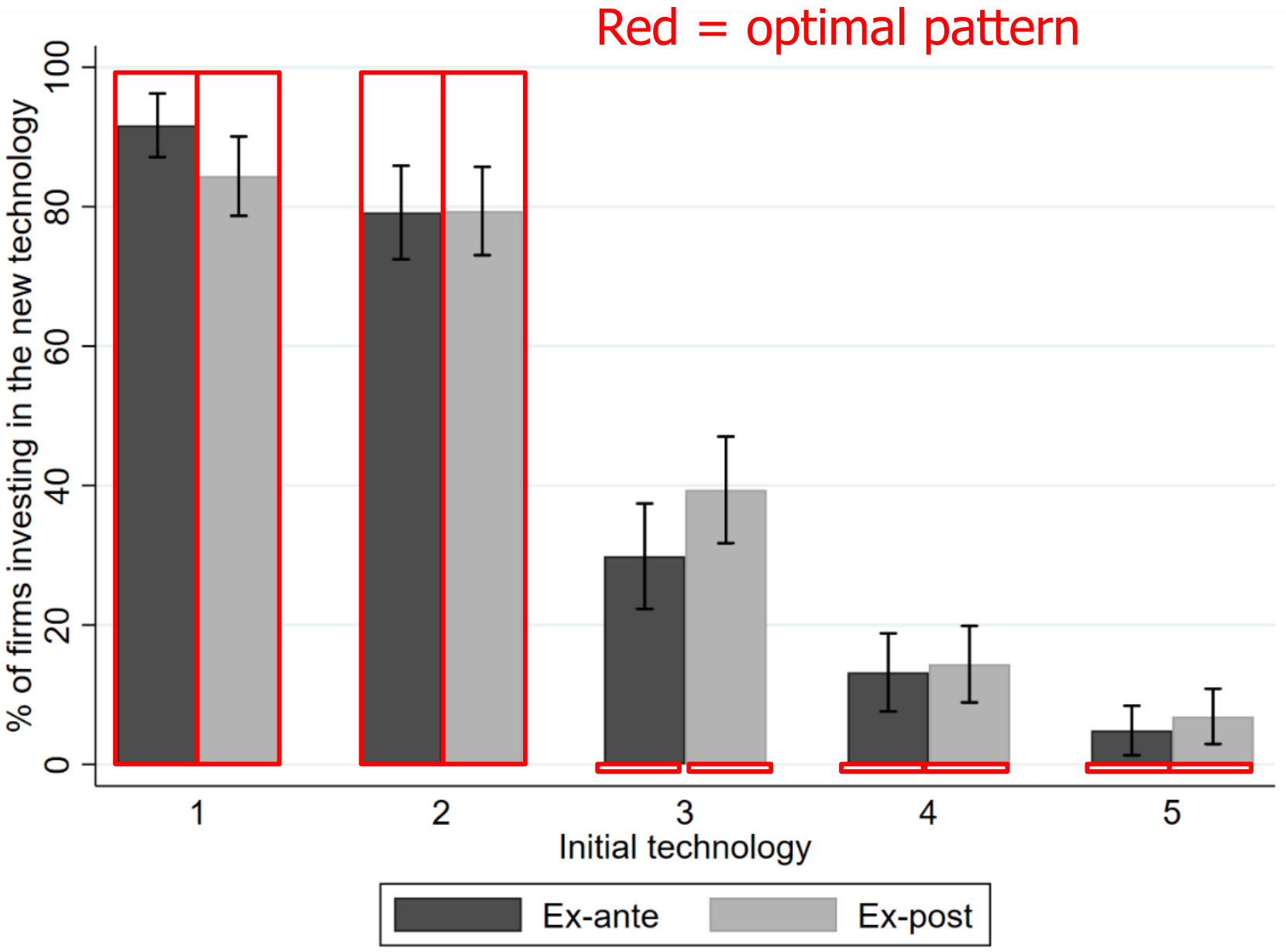
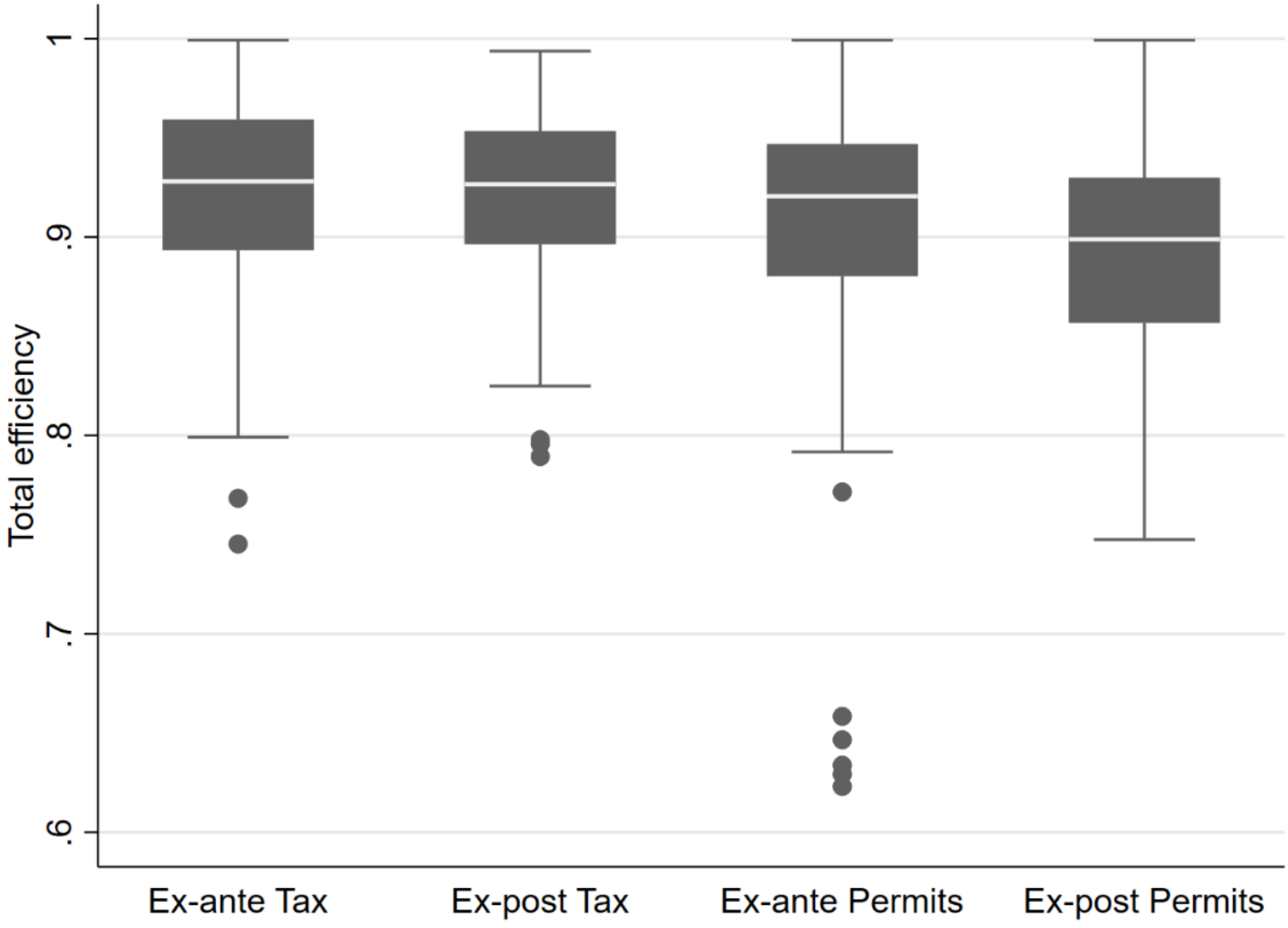


Table 3: Linear Probability model estimations: Adoption of the advanced technology

	Model 1	Model 2
Ex-post Tax	0.100	0.085
	(0.092)	(0.092)
Ex-ante Permits	-0.015	-0.010
	(0.089)	(0.091)
Ex-post Permits	0.050	-0.004
	(0.078)	(0.088)
Initial Tech	-0.233***	-0.238***
	(0.005)	(0.011)
Round	-0.006***	-0.006***
	(0.002)	(0.002)
Ex-post Tax × Initial Tech	-	0.005
		(0.015)
Ex-ante Permits × Initial Tech	-	-0.001
		(0.015)
Ex-post Permits × Initial Tech	-	0.018
		(0.016)
Constant	1.149***	1.165***
	(0.053)	(0.055)
Group FE	Yes	Yes
Observations	3120	3120
R-squared	0.443	0.443

Note: The dependent variable is technology adoption in round t by firm i. 'Ex-ante Tax' serves as the baseline treatment. "Initial Tech" is the initial technology ordered from the dirties (T_1) to the cleanest (T_5). Std. errs. (in parentheses) are two-way clustered across (i) *individuals* and (ii) *groups* × *rounds*. Finally, ***, **, and * denote significance at the 1%, 5%, and 10%, respectively

Efficiency of regimes



Major findings

- Ex ante and ex post taxation do not perform significantly different.
- Ex ante permit policy also does not perform significantly different from taxation:
  "Prices equivalent to quantities"
- Ex post permit policy performs slightly worse.

Sources of inefficiencies

There are three sources of inefficiencies:

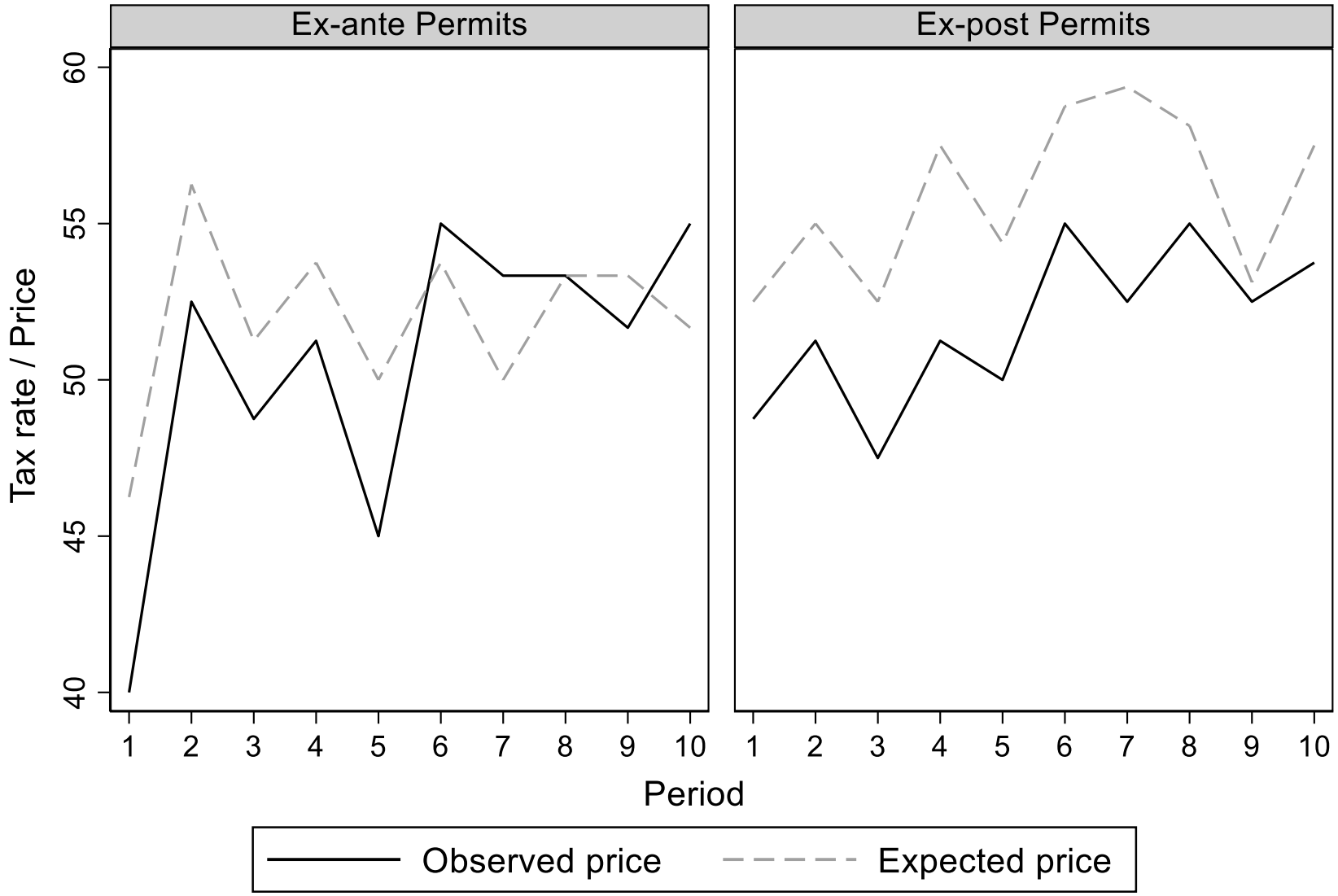
1) Static: suboptimal abatement decision or suboptimal emissions trading

2) Dynamic: suboptimal investment

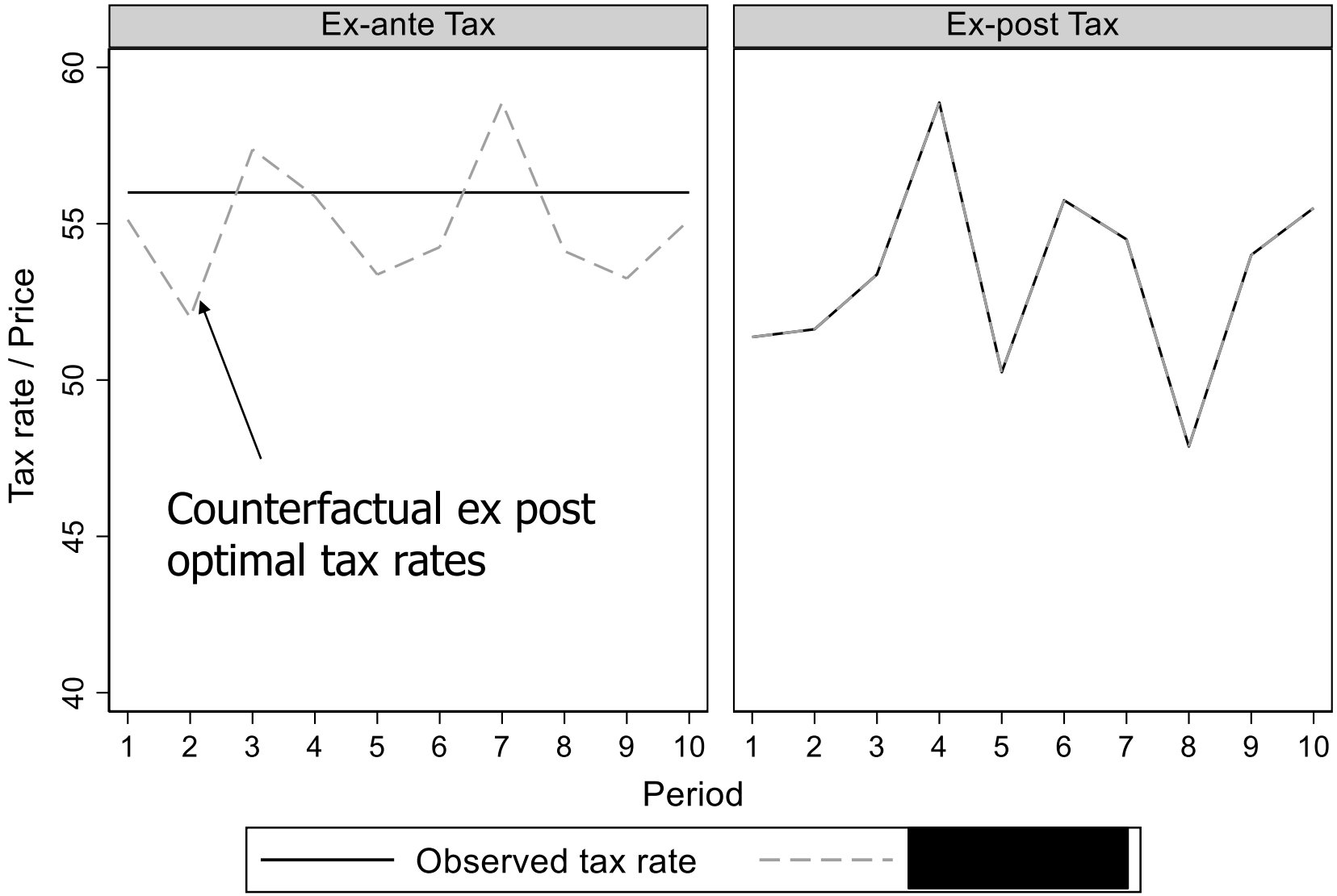
3) Regulatory: through commitment.

Disentangling the sources from the data, did not yield provide significant differences.

Expected and observed prices (permits treatments)



Ex ante vs ex post optimal tax rates



Graphs by Treatment

Thank you!

Appendix tables

Table C.1: Pre-analysis. Linear Probability model estimations: Adoption of an advanced technology in lab vs. online groups

	Ex-ante Tax	Ex-post Tax	Ex-ante Permits	Ex-post Permits
Initial Tech T_2	0.025	-0.131***	-0.125***	-0.050
	(0.036)	(0.042)	(0.044)	(0.040)
Initial Tech T_3	-0.650***	-0.488***	-0.618***	-0.450***
	(0.052)	(0.049)	(0.057)	(0.049)
Initial Tech T_4	-0.756***	-0.787***	-0.785***	-0.700***
	(0.052)	(0.045)	(0.045)	(0.056)
Initial Tech T_5	-0.800***	-0.837***	-0.868***	-0.775***
	(0.046)	(0.040)	(0.038)	(0.042)
Round	-0.003	-0.005	-0.005	-0.009**
	(0.003)	(0.004)	(0.004)	(0.004)
Online	0.060	0.040	0.007	0.050
	(0.062)	(0.095)	(0.092)	(0.085)
Constant	0.875***	0.957***	0.907***	0.864***
	(0.058)	(0.064)	(0.052)	(0.068)
Group FE	yes	yes	yes	yes
R-squared	0.558	0.461	0.509	0.423
Observations	800	800	720	800

Note: The dependent variable is technology adoption in round t by firm i. ' Std. errs. (in parentheses) are two-way clustered across (i) *individuals* and (ii) *groups* $\times$ *rounds*. Finally, ***, **, and * denote significance at the 1%, 5%, and 10%, respectively

Table C.2: Pre-analysis. Linear model estimations: Emissions in lab vs. online groups

	Ex-ante Tax	Ex-post Tax	Ex-ante Permits	Ex-post Permits
Initial Tech T_2	0.006	1.000**	1.083**	0.087
	(0.449)	(0.434)	(0.474)	(0.440)
Initial Tech T_3	5.656***	3.881***	4.222***	3.113***
	(0.536)	(0.460)	(0.572)	(0.498)
Initial Tech T_4	4.750***	4.619***	4.556***	3.337***
	(0.495)	(0.411)	(0.490)	(0.527)
Initial Tech T_5	3.012***	3.481***	3.174***	1.988***
	(0.463)	(0.362)	(0.444)	(0.411)
Round	0.004	-0.004	0.009	0.024
	(0.028)	(0.024)	(0.018)	(0.014)
Online	-0.510	0.380	-0.175	-0.160
	(0.589)	(0.727)	(1.277)	(0.736)
Constant	3.495***	3.055***	3.104***	3.515***
	(0.576)	(0.601)	(0.586)	(0.614)
Group FE	yes	yes	yes	yes
R-squared	0.350	0.230	0.205	0.141
Observations	800	800	720	800

Note: The dependent variable is emissions in round t by firm i. ' Std. errs. (in parentheses) are two-way clustered across (i) *individuals* and (ii) *groups* × *rounds*. Finally, ***, **, and * denote significance at the 1%, 5%, and 10%, respectively

Table C.3: Probit model estimations: Adoption of an advanced technology

	Model 1	Model 2
Ex-post Tax	0.404	0.302
	(0.384)	(0.425)
Ex-ante Permits	-0.026	0.095
	(0.375)	(0.426)
Ex-post Permits	0.203	-0.084
	(0.337)	(0.406)
Initial Tech	-0.786***	-0.814***
	(0.037)	(0.077)
Round	-0.025***	-0.024***
	(0.008)	(0.008)
Ex-post Tax × Initial Tech	-	0.036
		(0.101)
Ex-ante Permits × Initial Tech	-	-0.042
		(0.111)
Ex-post Permits × Initial Tech	-	0.100
		(0.102)
Constant	2.171***	2.249***
	(0.247)	(0.276)
Group FE	Yes	Yes
Observations	3120	3120
Pseudo R-squared	0.3784	0.3795

Note: The dependent variable is technology adoption in round t by firm i. "Ex-ante Permits" serves as the baseline treatment. "Initial Tech" is the initial technology ordered from the dirties (T_1) to the cleanest (T_5). Std. errs. (in parentheses) are two-way clustered across (i) *individuals* and (ii) *groups* × *rounds*. Finally, ***, **, and * denote significance at the 1%, 5%, and 10%, respectively

TUS EMISIONES						REDUCIR EMISIONES		
TC1	TC2	TC3	TC4	TC5	Nueva Tecnología	Coste MARGINAL	Coste TOTAL	Unidades REDUCIDAS
20	18	16	14	12	7	----	0	0
19	17	15	13	11	6	10	10	1
18	16	14	12	10	5	20	30	2
17	15	13	11	9	4	30	60	3
16	14	12	10	8	3	40	100	4
15	13	11	9	7	2	50	150	5
14	12	10	8	6	1	60	210	6
13	11	9	7	5	0	70	280	7
12	10	8	6	4		80	360	8
11	9	7	5	3		90	450	9
10	8	6	4	2		100	550	10
9	7	5	3	1		110	660	11
8	6	4	2	0		120	780	12
7	5	3	1			130	910	13
6	4	2	0			140	1050	14
5	3	1				150	1200	15
4	2	0				160	1360	16
3	1					170	1530	17
2	0					180	1710	18
1						190	1900	19
0						200	2100	20

Computer screens

Auswahl der Technologie

Tech 3
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

Grenzkosten	Totale Vermeidungskosten	Vermiedene Einheiten
0	0	0
10	10	1
20	30	2
30	60	3
40	100	4
50	150	5
60	210	6
70	280	7
80	360	8
90	450	9
100	550	10
110	660	11
120	780	12
130	910	13
140	1050	14
150	1200	15
160	1360	16
170	1530	17
180	1710	18
190	1900	19
200	2100	20

Runde 1 von 2

Dir wurde Technologie 3 mit einem maximalen Emissionsniveau von 16 zugeteilt.

Um die Neue Technologie einzusetzen, musst Du Investitionskosten von 580 ECU zahlen.

Möchtest Du in die Neue Technologie investieren?

Weiter

Auktion

Verbleibende Zeit für diese Seite. **0:58**

Neue
7
6
5
4
3
2
1
0

Grenzkosten	Totale Vermeidungskosten	Vermiedene Einheiten
0	0	0
10	10	1
20	30	2
30	60	3
40	100	4
50	150	5
60	210	6
70	280	7
80	360	8
90	450	9
100	550	10
110	660	11
120	780	12
130	910	13
140	1050	14
150	1200	15
160	1360	16
170	1530	17
180	1710	18
190	1900	19
200	2100	20

Runde 1 von 18

Du benutzt Technologie Neue mit einem maximalen Emissionsniveau von 7.

Die Anzahl der Emissionszertifikate (N) ist 68.

Der Preis für Emissionszertifikate beträgt in dieser Runde 5.

Wieviele Emissionszertifikate willst du bei diesem Preis kaufen?

Weiter

Taschenrechner

1+1

= C

Additional table

TUS EMISIONES						REDUCIR EMISIONES		
TC1	TC2	TC3	TC4	TC5	Nueva Tecnología	Coste MARGINAL	Coste TOTAL	Unidades REDUCIDAS
20	18	16	14	12	7	----	0	0
19	17	15	13	11	6	10	10	1
18	16	14	12	10	5	20	30	2
17	15	13	11	9	4	30	60	3
16	14	12	10	8	3	40	100	4
15	13	11	9	7	2	50	150	5
14	12	10	8	6	1	60	210	6
13	11	9	7	5	0	70	280	7
12	10	8	6	4		80	360	8
11	9	7	5	3		90	450	9
10	8	6	4	2		100	550	10
9	7	5	3	1		110	660	11
8	6	4	2	0		120	780	12
7	5	3	1			130	910	13
6	4	2	0			140	1050	14
5	3	1				150	1200	15
4	2	0				160	1360	16
3	1					170	1530	17
2	0					180	1710	18
1						190	1900	19
0						200	2100	20