Reducing Air Pollution through Behavioral Change of Wood-Stove Users: Evidence from an RCT in Valdivia, Chile

Cristobal Ruiz-Tagle **Alejandra Schueftan**

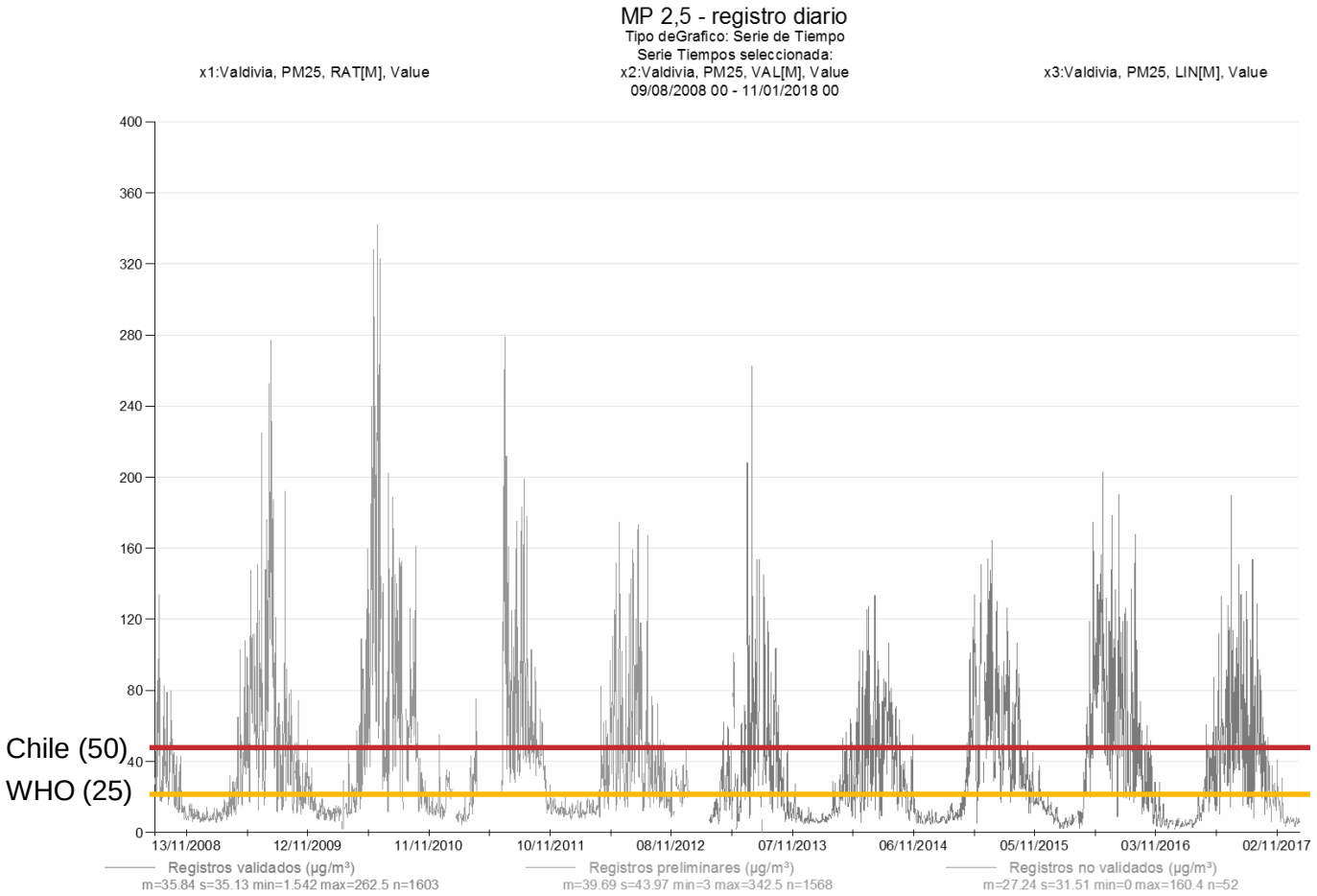
Presentation for LEEP Institute's Meeting of
International Excellence in Environmental and Resource Economics
University of Exeter Business School, 25th June 2019

Background

- High concentrations of <u>outdoor</u> air pollution due to widespread use of wood-fuel (largely) for heating
  - Air pollution concentrations far exceed safe levels

Picture

Table



Introduction

- More than 90% of households use woodstoves for heating
- Gov't subsidizes conversion to new (clean) wood-stoves
- Most households (9/10) *choke* their woodstoves airflow
  - Makes wood-fuel last longer and saves fuel consumption
  - Increases air pollution emission by 5 to 6 times (w.r.t. efficient use)
    - When choked air pollution emissions are no different to that of old (dirty) wood-stoves

  → Clean air as a local public good
- Behavioral intervention → *Information sign* that informs users on pollution emissions when choking woodstove's airflow

Wood-stove & Information signage

Most common wood-stove in Chile's south-central cities (such as Valdivia)

Highly subsidized (~ USD 200)

Information sign

POLLUTION EMISSIONS

Very High | High | Mid-level | Low | Ignition

Damper setting

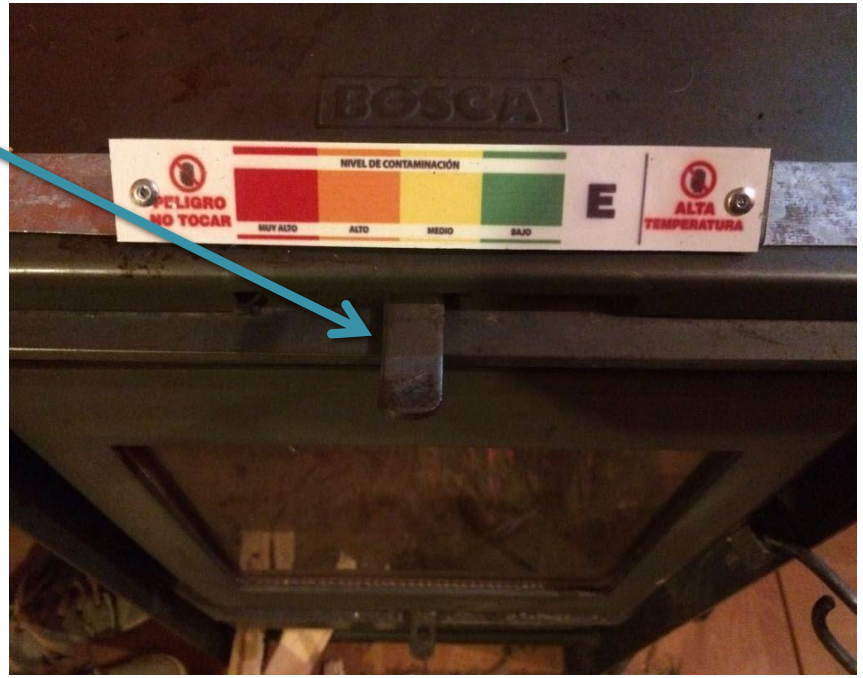
Choked	Mostly Choked	Mid-level	Mostly Open	Open

Combustion detail

Wood-stove & Information Sign

Damper adjusts the airflow inside the wood-stove's combustion chamber

Flyer



Damper's setting recording device

Cost of signage ~ USD 5

Experimental design

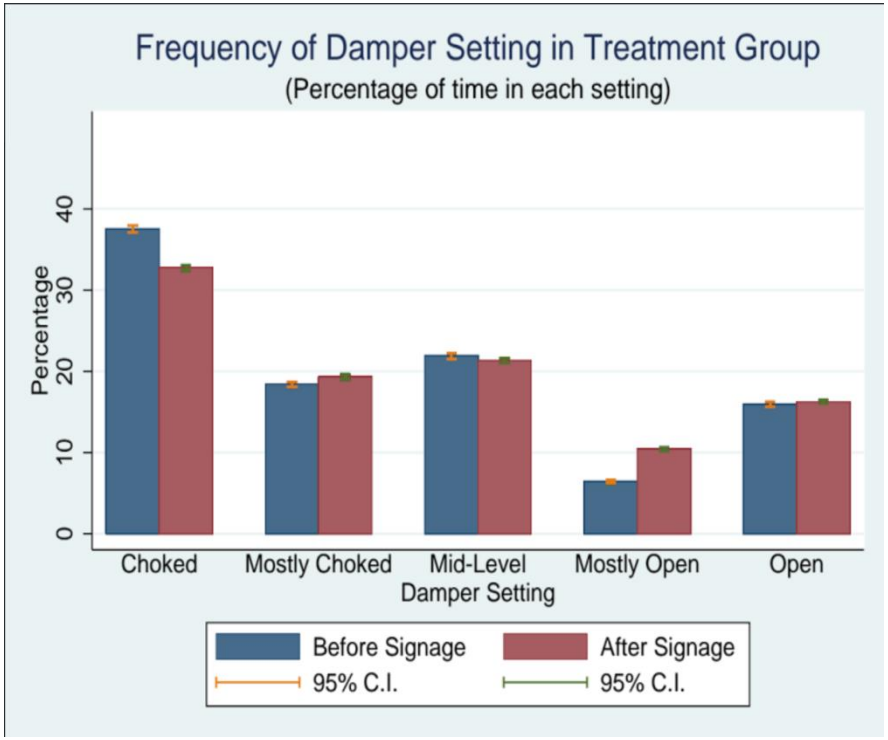
- 80 participating households that use a wood-stove as main source of heating
- Damper setting recording device installed in all 80 HHs
- *Information sign* was installed on half the HH's woodstoves (random assignment) after a two-week period
- HHs members were not aware of whether they were in treatment or control group, and no evidence of communication among participating HHs
- Incentive for participation: 1 m^3 certified-dry wood-fuel (worth ~ USD 60, or 15% of Chile's monthly minimum wage)

Randomization

	Treatment Group		Control Group	
Variables	Mean	S.D.	Mean	S.D.
Household members	3.15	1.03	3.37	1.46
Less than 4 years old	0.19	0.48	0.19	0.44
Between 5 and 14	0.30	0.54	0.50	0.75
Between 15 and 65	2.44	1.15	2.33	1.32
65 and older	0.22	0.58	0.35	0.56
HH member suffer from resp. or cardio. disease	0.26	0.45	0.25	0.44
Num. hours woodstove is in use				
Weekdays	13.4	6.3	12.3	5.0
Weekends	14.9	6.5	15.5	4.8
Indoor temp. score (self reported)	0.88	0.12	0.88	0.11
Monthly HH income (perc.)				
Less than USD 800	0.41	0.50	0.42	0.50
Between USD 800 - 1,700	0.33	0.48	0.38	0.49
More than USD 1,700	0.19	0.40	0.19	0.40
Dwelling's				
Ownership = own (perc.)	0.70	0.47	0.71	0.46
Surface area (sq. meter)	70.6	39.2	78.6	39.6
Floors (perc. 1 floor)	0.37	0.49	0.38	0.49
Construction before year 2000	0.56	0.51	0.60	0.50
Const. between 2000 and 2007	0.19	0.40	0.21	0.41
Const. after 2007	0.11	0.32	0.06	0.24
Const. year N/A	0.15	0.36	0.12	0.32
Respondent's				
Gender (1=male)	0.41	0.50	0.40	0.50
Age	43.0	13.8	47.3	14.2
Marital status = single (perc.)	0.33	0.48	0.31	0.47
Marital status = married (perc.)	0.44	0.51	0.58	0.50
Marital status = divorced/widowed	0.22	0.42	0.12	0.32
Educ. attainment = primary (perc.)	0.15	0.36	0.19	0.40
Educ. attainment = secondary (perc.)	0.41	0.50	0.37	0.49
Educ. attainment = Terc. (technical)	0.19	0.40	0.19	0.40
Educ. attainment = Terc. (university)	0.26	0.45	0.25	0.44

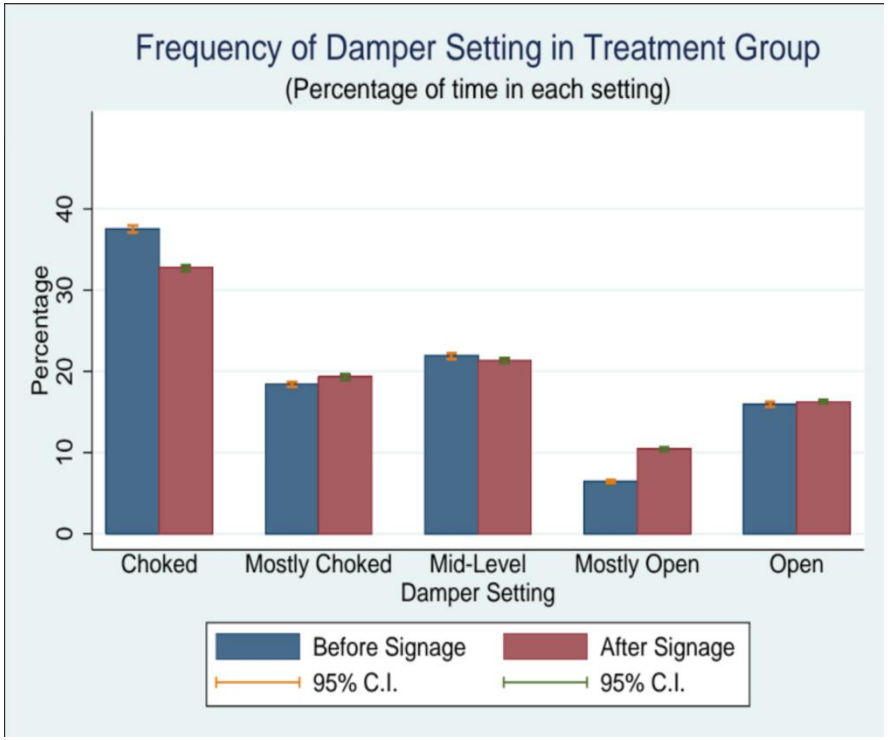
Results

Treatment Group

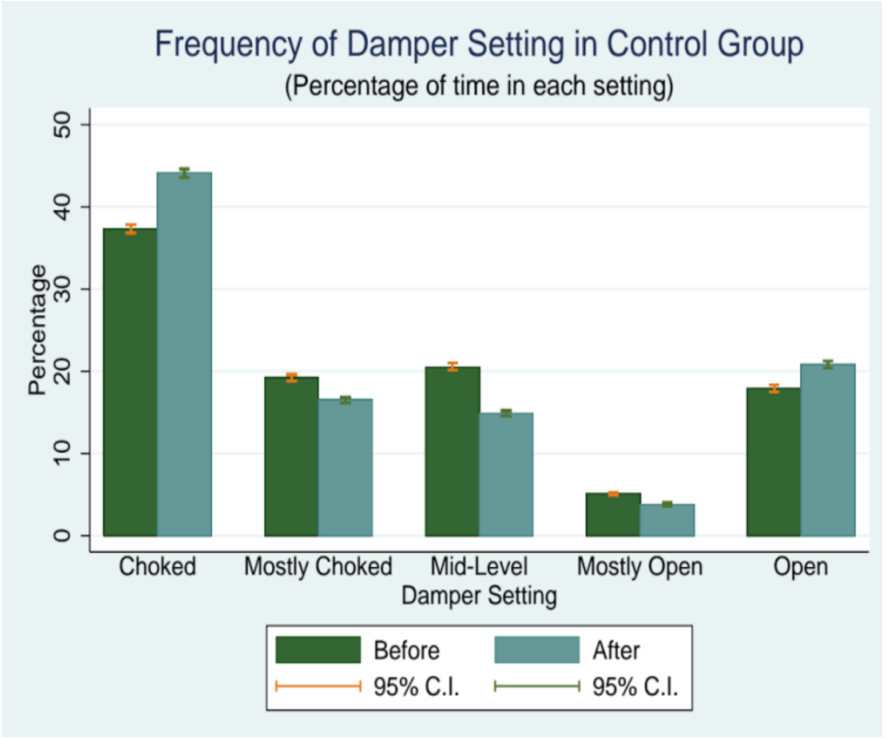


Results

Treatment Group

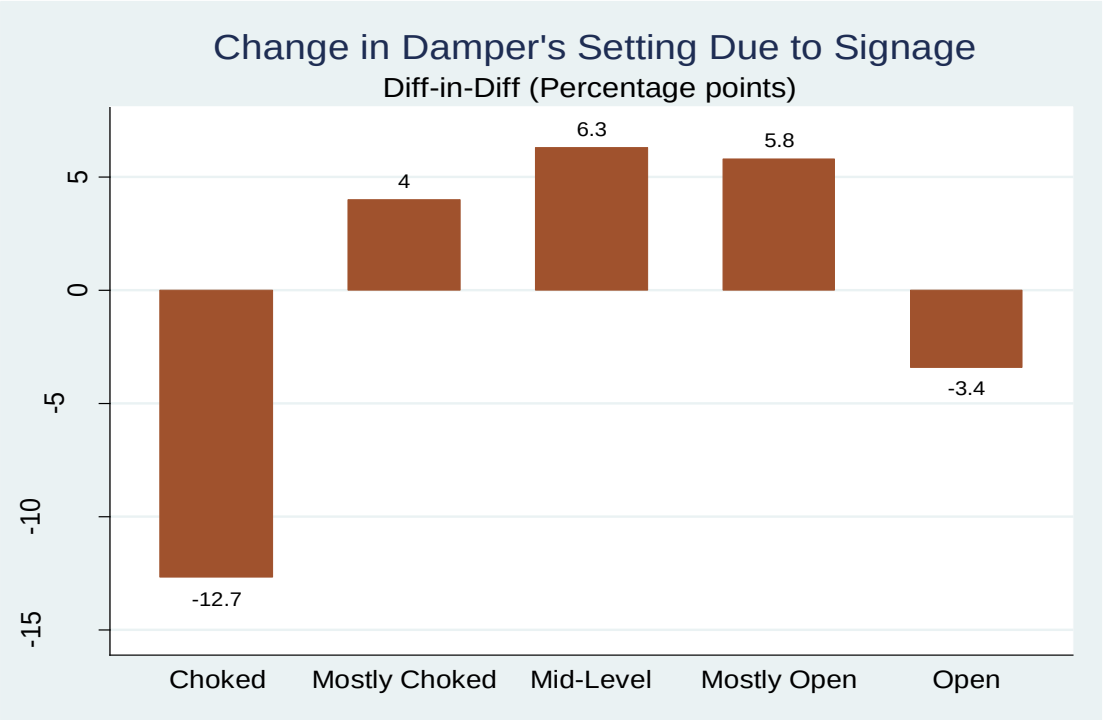


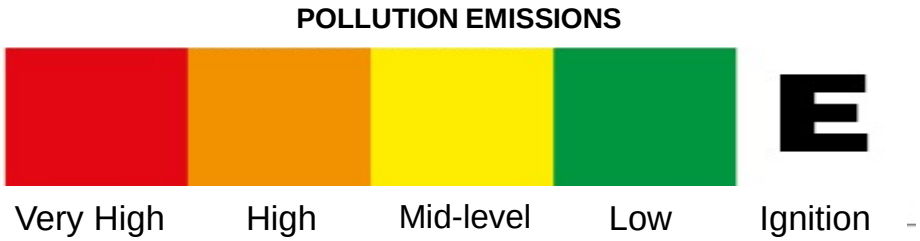
Control Group



Results – Behavioral Change in Use of Damper Setting

Treatment vs Control (Diff-in-Diff)





Diff-in-Diff in Regression Framework

- OLS Framework. Position $Y_j = 0,1 \ldots, 5$

$$Y_j = \beta_0 + \beta_1 Sign + \beta_2 TreatGr + \beta_3 SignTrGr + \gamma X + \epsilon$$

- Multinomial Logit Framework. Setting *Choked* (*C*) as baseline
  - $\Pr(j|S, G, j = C) =$

$$\frac{1}{1 + \sum_{j \neq C} \exp(\beta_0^{(j)} + \beta_1^{(j)} Sign + \beta_2^{(j)} TreatGr + \beta_3^{(j)} SignTrGr + \gamma^{(j)} X)}$$

  - $\Pr(j|S, G, j \neq C) =$

$$\frac{\exp(\beta_0^{(j)} + \beta_1^{(j)} Sign + \beta_2^{(j)} TreatGr + \beta_3^{(j)} SignTrGr + \gamma^{(j)} X)}{1 + \sum_{j \neq C} \exp(\beta_0^{(j)} + \beta_1^{(j)} Sign + \beta_2^{(j)} TreatGr + \beta_3^{(j)} SignTrGr + \gamma^{(j)} X)}$$

Results – Diff-in-Diff Regression Framework

Panel A: Parameter Estimates from Multinomial Logit Regression

	Choked	Mostly Choked	Mid-Level	Mostly Open	Open	Choked	Mostly Choked	Mid-Level	Mostly Open	Open
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sign On		-0.0456**	-0.00639	0.148***	-0.114***		-0.0486**	0.165***	0.390***	0.0110
		(0.0210)	(0.0200)	(0.0332)	(0.0214)		(0.0217)	(0.0205)	(0.0343)	(0.0221)
Treatment Group		-0.332***	-0.585***	-0.553***	-0.0372		-0.344***	-0.567***	-0.506***	-0.0167
		(0.0242)	(0.0243)	(0.0423)	(0.0234)		(0.0247)	(0.0246)	(0.0427)	(0.0237)
Sign On & Treatment Gr.		0.551***	0.693***	1.193***	0.148***		0.539***	0.717***	1.188***	0.144***
		(0.0294)	(0.0291)	(0.0482)	(0.0293)		(0.0300)	(0.0296)	(0.0488)	(0.0298)
Constant		-0.690***	-0.554***	-1.932***	-0.731***		-1.956***	0.941***	-2.380***	-0.289***
		(0.0170)	(0.0163)	(0.0276)	(0.0173)		(0.0665)	(0.0654)	(0.107)	(0.0700)
Controls	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Observations	173,157	173,157	173,157	173,157	173,157	173,157	173,157	173,157	173,157	173,157

Standard errors clustered at the household level. *** p<0.01, ** p<0.05, * p<0.1

Panel B: Frequency of Damper Setting Using Parameter Estimates from Multinomial Logit Regression (percentages)

	Choked	Mostly Choked	Mid-Level	Mostly Open	Open	Choked	Mostly Choked	Mid-Level	Mostly Open	Open
Treatment Gr., Before	37.8	18.1	21.6	6.3	16.2	38.1	17.4	22.6	6.0	16.0
Treatment Gr., After	33.0	19.7	21.0	10.5	15.8	33.0	18.3	22.7	10.3	15.7
Control Gr., Before	37.0	18.6	21.3	5.4	17.8	39.9	19.1	20.1	4.3	16.6
Control Gr., After	44.9	16.1	14.4	3.7	20.8	47.7	16.2	13.6	3.1	19.5
Diff-in-Diff	**-12.7**	**4.0**	**6.3**	**5.8**	**-3.4**	**-12.8**	**3.9**	**6.6**	**5.5**	**-3.1**

Emissions' reduction due to signage

$PM_{2.5}$ Emission Factors by Damper Setting (g/h)

	Damper Setting		
Wood-fuel's moisture	Choked	Mid-Level	Mostly Open
Dry (certified)	17.1	6.1	4.4
High moist content	40.5	9.8	8.7

- Reduction of 12.7 % in frequency of *choked* damper setting (pollution emissions = *very high*)
- This translates to a 17.3 % reduction in pollution emissions
  - 14.7 % decrease when using certified-dry wood-fuel
  - 18.7 % decrease when using high moisture wood-fuel
- Cost of signage ~ USD 5

Results detail

THANK YOU !

Global Problem of Ambient Air Pollution

Most polluted cities in South America are in Chile

World most polluted cities 2018 (PM2.5)

Like 10K

Filter cities by

Continent: South America | Country/Region: All | State: All | City:

2018 NEW — IQAir AirVisual

Download world air quality report 2018

Download PDF — English

PM2.5 Legend: WHO target | Good | Moderate | Unhealthy for sensitive groups | Unhealthy | Very unhealthy | Hazardous

Unit: µg/m³

Rank	City	2017 AVG	2018 AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Padre las Casas, C...	38.8	43.3	4.6	7.3	16.6	65.4	69.3	100.2	103.7	93	43.3	26.2	14	-
2	Osorno, Chile	30.8	38.2	8.9	10.7	20.6	61.5	62.5	70	96.4	65.3	40.9	24	13.5	-
3	Coyhaique, Chile	39.3	34.2	6.7	7.3	21.6	39.4	88.6	166.8	92.5	73.2	38.3	29.7	18.1	-
4	Valdivia, Chile	33.5	33.3	5.2	5.5	11.9	47.8	60.2	70.9	75.5	61.4	35.1	25	14.5	-
5	Temuco, Chile	28.7	30.4	2.7	2.8	10.8	46.5	56.8	68.3	73.3	62.6	30	18.3	9.6	-
6	Santiago, Chile	23.1	29.4	13.7	14.7	15.9	23.6	44.9	63.9	53.6	41.5	22.6	14.1	10.3	-
7	Lima, Peru	27.7	28	23.7	21.3	31.5	26.4	41	40.9	25.7	28.2	30	23.9	24.2	20.9
8	Linares, Chile	27.1	25.5	6.4	9.3	9	28.5	52.1	85.1	66.1	53.6	20	8	4.7	-
9	Rancagua, Chile	23.3	22.9	11.4	10.4	11.1	18.4	27.9	56.2	52.9	42.5	23.2	13.7	7.8	-
10	Puerto Montt, Chile	29.6	22.6	9.3	8.5	14.5	19.6	27.8	28.9	74.5	31.3	25.8	15.3	12.8	-

Air Pollution Emissions from HHs Wood-stoves

Most common wood-stove in Chile's south-central cities (such as Valdivia)

Wood-stove's 'double combustion' technology for low air pollution emissions and efficient heating

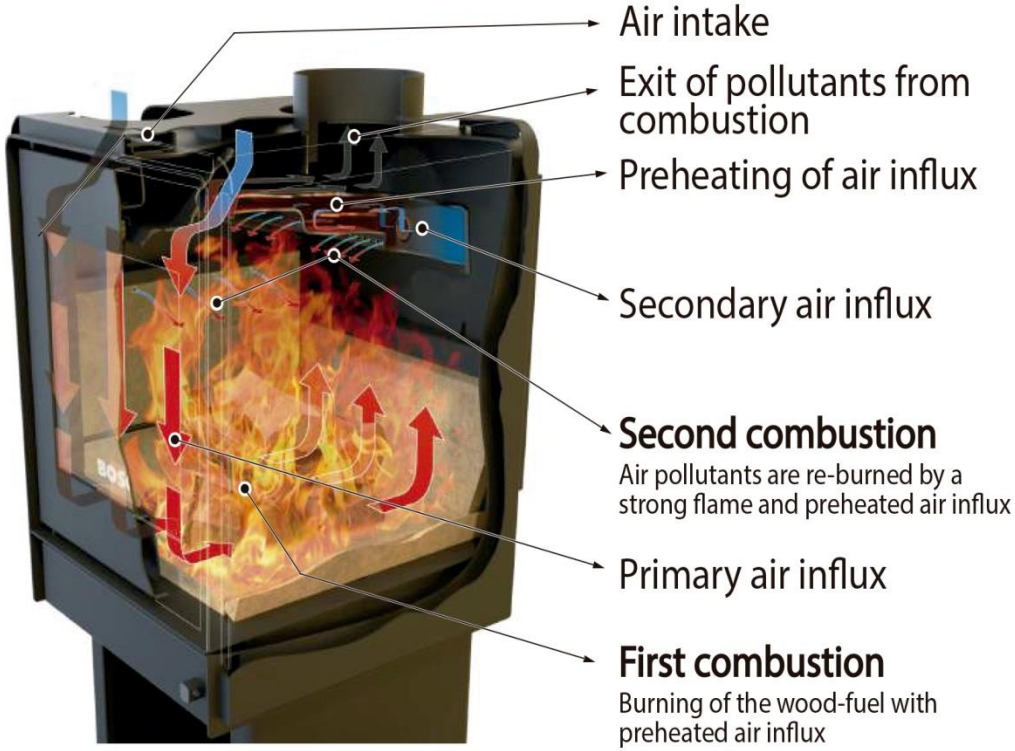


Table 5: Damper Setting Usage, $PM_{2.5}$ Emissions and Effect of Information Signage on $PM_{2.5}$ Emissions

	Total	Damper Setting		
		Choked	Mid-Level	Mostly Open
Frequency of damper setting usage (%)[1]		37.4	39.7	22.9
Change of damper setting usage due to sign (percentage points)[2]		-12.7	10.3	2.4
	Dry Wood-Fuel (certified)			
$PM_{2.5}$ emissions before sign (g/h)[3]	**9.8**	6.4	2.4	1.0
Reductions in $PM_{2.5}$ emissions due to sign (g/h)[4]	**1.4**	2.2	-0.6	-0.1
	High Moisture Wood-Fuel			
$PM_{2.5}$ emissions before sign (g/h)[3]	**21.0**	15.1	3.9	2.0
Reductions in $PM_{2.5}$ emissions due to sign (g/h)[4]	**3.9**	5.1	-1.0	-0.2

(1): Average damper setting across treatment and control groups before signage. Settings 'mostly choked' and 'Mid-level' were agregated into column 'Mid-Level', and setting 'Mostly Open' was agregated with 'Open'. See Figure 8 and Figure 9, or Panel B Table 3.

(2): Settings 'mostly choked' and 'choked' were agregated into column 'Mid-Level', and setting 'Mostly Open' was agregated with 'Open'. See Figure 10 or Panel B Table 3.

(3): Average $PM_{2.5}$ emissions in grams per hour (g/h). Emissions for each damper setting is a weighted average calculated by multiplying frequency of damper setting (first row) by emission factors from Table 4.

(4): Reductions in $PM_{2.5}$ emissions in grams per hour (g/h). Emissions for each damper setting is a weighted average calculated by multiplying change of damper setting due to signage (second row) by emission factors from Table 4.

USO DEL TIRAJE DE NUESTRAS ESTUFAS A LEÑA

¿CÓMO AFECTA AL AIRE QUE RESPIRAMOS?

Valdivia sufre de **altos niveles de contaminación**, debido al uso ineficiente de las estufas a leña.

El **uso del tiraje** incide en la contaminación que éstas emiten.

¿CÓMO?

El tiraje cerrado emite mucho más contaminación que el tiraje abierto.

* Esta contaminación, también entra al interior de la vivienda a través de **puertas, ventanas y filtraciones.**

SEÑALÉTICA

La señalética instalada, representa los **niveles de contaminación de su estufa** en las distintas posiciones del tiraje.