The Behavioral Effect of Pigovian Regulation: Evidence From a Field Experiment

Lanz, Wurlod, Panzone, and Swanson (2018)

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EconS 582

24 February 2020

Overview

1. Introduction and research objective
2. Experimental design
3. Contribution to existing literature
4. Methodology
5. Results
6. Conclusion

Introduction

Pigovian Regulation

- Pricing incentive
- Agents internalize their actions

Behavioral Implications

- How agents process policy information
- Behavioral traits can effect policy design

Introduction - Behavioral Aspects

Evidence from economics and experimental psychology

- Pricing incentives can have negative impacts
- Self-image, short- and long-run differences (Gneezy et al., 2011)
- Altruism, ethical norms, intrinsic incentive for public service (Bowles and Polanía-Reyes, 2012)

Result: Pigovian regulation for promoting pro-social behavior can dampen the effect of agents' self-motivating actions absent regulation

Introduction - Research Objective

Literature coverage

- Theoretical properties of Pigovian pricing well-understood
- Empirical evidence of its relevance for policy design is lacking

Literature growth

- Market-based instruments for environmental policy (e.g. cap and trade)
- Inexpensive nature of non-price incentives (Allcott, 2011)
- Behavioral public finance (Chetty et al., 2009)

Objective: Quantify policy implications of behavioral effects associated with Pigovian intervention

Experimental Design

Field experiment in 7 London grocery stores (Perino et al., 2014)

- Consumers make *real* consumption decisions
- Choice set composed of clean and dirty alternatives (embodied carbon emissions)

Randomized into product attribute treatment groups

- Information about embodied emissions (no price incentive effect)
- Pigovian price change proportional to external costs with regulatory information regarding the price signal
- Pigovian price change but with no regulatory information (market-based price difference)

Incentive compatibility satisfied with a voucher for consumption compliance (96%)

Experimental Design - Original Study

Perino et al. (2014) conducted the experiment to analyze how consumers respond to government intervention

- Consumer intrinsic motivation is important
- Intervention can result in crowding in (positive) or crowding out (negative)

$\Rightarrow$ Motivation crowding

Experimental Design - Original Study

Structure

- Analyze crowding effects of labeling, subsidy, and neutral price change interventions on decision-making
- Aggregate product scope looking at cola, meat, milk, and spreads
- DID empirical strategy

Result: Labeling induces intrinsic motivation for clean consumption, subsidy induces smaller change (crowding out)

$\Rightarrow$ Inexpensive non-price incentives more effective

Experimental Design - Current Study

Lanz et al., (2018) disaggregate product scope to look at individual product decisions

- Carbon content across product categories is heterogeneous
- Substitutability between clean and dirty alternatives varies across products

Empirical strategy moves away from aggregate product treatment effects (DID)

Product choices are used to estimate a structural demand model for differentiated products (Multinomial choice)

Contribution - Modeling Approach

Structural demand model quantifies substitutability between clean and dirty alternatives for the neutrally-framed price change

- Can evaluate the effectiveness of intervention based on substitutability

Structural demand model allows estimation of money-metric welfare measures associated with treatments

Contribution - Equivalent Price Metric (EPM)

Chetty et al. (2009) and Allcott and Taubinsky (2015)

- Effect on market share with tax-inclusive information
- Information on Pigovian pricing is more effective in reducing demand
- Salience is an important determinant of behavioral response
- Individuals systematically make optimization errors

$\Rightarrow$ The general Pigovian outcome is not representative of the actual outcome

EPM in this context

- Measures change in relative prices that yields the same change in choice probabilities between clean and dirty alternatives

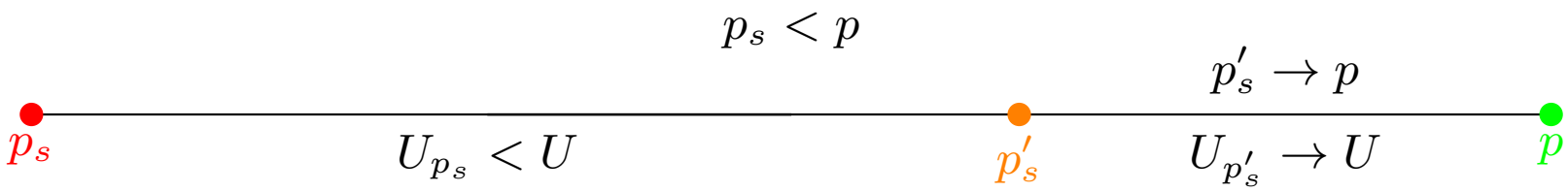
Contribution - EPM

EPM for **information** as the welfare measure in treatment context

- Estimates consumers' valuation of carbon reduction
- Compares consumer valuation to Pigovian price signal ($\approx$ social cost of product carbon emission)

EPM for quantifying **behavioral effect** of Pigovian intervention

- Differences in impact when framed as Pigovian intervention and market-based variation
- Measure of *increase in Pigovian price*(?) that compensates negative behavioral effect associated with intervention



Contribution - Key Takeaways

1. Disaggregate, structural approach for evaluating clean and dirty choices
2. EPM welfare measurements quantify information and behavioral effect of Pigovian intervention

Methodology - Consumer Choice

Table 1
Product categories and clean / dirty alternatives.

Products	Clean alternatives			Dirty alternatives		
	Options	Price (GBP)	Emissions ($kgCO_2$)	Options	Price (GBP)	Emissions ($kgCO_2$)
Cola	Coca Cola in PET bottle (2 l)	1.69	0.50	Coca Cola in ALU cans (2 l)	2.85	1.02
	Coca Cola Diet in PET bottle (2 l)	1.69	0.50	Coca Cola Diet in ALU cans (2 l)	2.85	1.02
	Coca Cola Zero in PET bottle (2 l)	1.69	0.50	Coca Cola Zero in ALU cans (2 l)	2.85	1.02
	Pepsi Regular in PET bottle (2 l)	1.00–1.69	0.50	Pepsi Regular in ALU cans (2 l)	2.75	1.02
	Pepsi Diet in PET bottle (2 l)	1.00–1.69	0.50	Pepsi Diet in ALU cans (2 l)	2.75	1.02
	Pepsi Max in PET bottle (2 l)	1.00-1.69	0.50	Pepsi Max in ALU cans (2 l)	2.75	1.02
Milk	Skimmed milk (2 pints)	0.86	1.40	Whole milk (2 pints)	0.86	1.80
				Semiskimmed milk (2 pints)	0.86	1.60
Spread	Lurpak Spread (500 g)	2.58	0.68	Lurpak butter (500 g)	2.76	11.90
	Sainsbury's spread (500 g)	1.00	0.68	Sainsbury's Basics butter (500 g)	1.76	11.90
	Anchor Spreadable (500 g)	2.18	0.68	Anchor butter (500 g)	2.40	11.90
	Flora Original spread (500 g)	1.18	0.68	Country life butter (500 g)	2.36	11.90
	Clover (500 g)	1.49	0.68	Kerrygold butter (500 g)	1.90	11.90
Meat	Chicken breast (300 g)	2.39	1.50	Beef braising steak (440 g)	3.49	7.04
	Chicken fillet (500 g)	2.18–4.00	2.50	Beef mince (500 g)	2.20	8.00
	Chicken thighs & drumsticks (721 g)	2.37–3.00	3.61	Diced casserole steak (440 g)	2.50	7.04

Notes: Table displays the exhaustive list of options available to consumers in each product category. For some alternatives in the cola and meat product categories the supermarket modified its price over the course of the experiment, and for consistency it was reflected in the experiment.

Methodology - Theoretical Framework

Let

U_n^j represent the utility individual n derives from consuming alternative j

p^j be the price of alternative j

$j = \{\text{clean, dirty}\}$

u_n^j represent observed and unobserved characteristics of j

$U_n^j = u_n^j - p^j$

Relative utility and prices

$u_n = u_n^{\text{dirty}} - u_n^{\text{clean}}$

$p = p^{\text{dirty}} - p^{\text{clean}}$

Methodology - Initial Product Choice

Consumers prefer the dirty alternative iff

$$U_n^{\text{dirty}} > U_n^{\text{clean}}$$

$$u_n^{\text{dirty}} - u_n^{\text{clean}} > p^{\text{dirty}} - p^{\text{clean}}$$

$$u_n > p$$

Methodology - Treatment Groups

Let

Δp represent a neutral price change

$\Delta e = e^{\text{dirty}} - e^{\text{clean}}$ represent relative CO_2 emissions

Δs represent a subsidy amount for the clean alternative

β_n^{price} represent change in relative utility induced by Δp

β_n^{info} represent a preference for the public good component of each product

β_n^{regul} represents behavioral impacts of Pigovian intervention above impact of Δp

β_n^{pigou} represent change in relative utility induced by Δs

Methodology - Treatment Relative Utility

Preferences for clean alternatives

Information

$$\beta_n^{\text{info}} \Delta e > u_n^{\text{dirty}} - p^{\text{dirty}} - (u_n^{\text{clean}} - p^{\text{clean}})$$

Pigovian

$$\beta_n^{\text{pigou}} \Delta s = \beta_n^{\text{price}} \Delta p + \beta_n^{\text{regul}} > u_n^{\text{dirty}} - p^{\text{dirty}} - (u_n^{\text{clean}} - p^{\text{clean}})$$

Neutrally-framed

$$\beta_n^{\text{price}} \Delta p > u_n^{\text{dirty}} - p^{\text{dirty}} - (u_n^{\text{clean}} - p^{\text{clean}})$$

Methodology - Multinomial Choice Model

Consider alternatives $j, i \in C$ with $j \neq i$

Individual n prefers j iff $U_n^j > U_n^i$, providing the choice probability

$$\text{Prob}(U_n^j > U_n^i) = P_n^j$$

U_n^C not directly observable

Methodology - Random Utility Model

McFadden (1974) utility decomposition

Let

ε_n^j represent individual stochastic preferences

V_n^j represent observable utility

Utility is then characterized as

$$U_n^j = V_n^j + \varepsilon_n^j$$

Methodology - Utility Link Function

Assume a linear functional form for observable utility

$$V_n^j = \gamma_n' Z^j + J_{\text{info}}^{\text{clean}} \beta_n^{\text{info}} \Delta e + J_{\text{pigou}}^{\text{clean}} \beta_n^{\text{pigou}} \Delta s + J_{\text{price}}^{\text{clean}} \beta_n^{\text{price}} \Delta p$$

Where

Z^j represents observable product attributes

$J_k^j = \mathbf{1}(k = \text{treatment}, j = \text{clean})$

γ, β^t represent parameters learned from the data

Methodology - Let's Get It Together

Recall choice probability statement

$$P_n^j = \text{Prob}(U_n^j > U_n^i)$$

$$\Rightarrow \text{Prob}(V_n^j + \varepsilon_n^j > V_n^i + \varepsilon_n^i)$$

$$\Rightarrow \text{Prob}(\varepsilon_n^i - \varepsilon_n^j < V_n^j - V_n^i)$$

Note the subscript n on stochastic preference indicates individual preferences are iid

Assume $\varepsilon_n \sim Gumbel(\eta, \mu)$ with η normalized to 1

Then $\varepsilon_n^i - \varepsilon_n^j \sim Logistic(\varepsilon) \Rightarrow F(\varepsilon) = \frac{e^{V_n^j}}{\sum_{j=1}^{C} e^{V_n^j}}$

Methodology - Likelihood Characterization

Let

$$y_{nt}^{j} = \begin{cases} 1 & \text{if individual } n \text{ chooses } j \text{ in choice } t \\ 0 & \text{otherwise} \end{cases}$$

Then

$$L(\gamma, \beta; y) = \prod_{n=1}^{N} \prod_{j=1}^{C} \prod_{t=1}^{2} (P_{nt}^{j})^{y_{nt}^{j}}$$

Methodology - Optimization Routine

Define the parameter of interest $\theta = \{\gamma, \beta\}$

$$\text{Prob}(y_{nt} = j) = \int_{\theta_n} \int_{\mu_n} P_n^j f(\theta, \mu|\psi) d(\mu_n) d(\theta_n)$$

Marginal distribution for parameter of interest θ

$$f(\theta|\psi) = \int_{\mu_n} f(\theta, \mu|\psi) d(\mu_n) = \int_{\mu_n} f(\theta|\mu_n \psi) f(\mu|\psi) d(\mu_n)$$

Many ways to sample

$\Rightarrow$ $\theta \sim \mathcal{N}(\phi, \psi)$ and $\mu \sim \mathcal{U}(-\psi, \psi)$

Average over μ and generate a chain $\{\theta_i\}_{i=1}^I$ for parameter convergence

Bootstrap θ for $se(\theta)$

Methodology - EPM Estimates

Generalization (Chetty et al., 2009; Allcott and Taubinsky, 2015)

$$\text{EPM}^{\text{treatment}} = \frac{D^{\text{treatment}}(p) - D(p)}{D'(p)}$$

The generalization informs EPMs of interest

$$\text{EPM}^{\text{info}} = \frac{\beta^{\text{info}}}{\beta^{\text{price}}}$$

$$\text{EPM}^{\text{regul}} = \frac{\beta^{\text{pigou}} \Delta s - \beta^{\text{price}} \Delta p}{\beta^{\text{price}}}$$

Methodology - EPM Interpretation

EPM^{info}

- Change in relative prices that generates behavioral change of the same magnitude as the information treatment

$\Rightarrow$ MRS between product carbon emissions and money

$\Rightarrow$ Consumers' monetary valuation of product carbon emissions

$\text{EPM}^{\text{regul}}$

- Behavioral effect of information provided by Pigovian intervention net of relative price change

$\Rightarrow$ Quantifies the change in relative prices that would compensate negative behavioral effects

Results - Overview

1. Model parameter estimates
2. Substitutability across product categories (control)
3. Information and Pigovian effects across product categories (treatment $\Rightarrow$ policy)
4. EPM for information and behavioral effect of Pigovian intervention

Results - Model Parameter Estimates

Table 5
Estimation of product-specific multinomial choice models.

	Cola			Milk			Spread			Meat		
	MNL (1)	MXL (2)		MNL (3)	MXL (4)		MNL (5)	MXL (6)		MNL (7)	MXL (8)	
		Mean	Std-dev.		Mean	Std-dev.		Mean	Std-dev.		Mean	Std-dev.
Information label	3.16***	10.12*	–	4.17***	4.30***	–	0.15***	1.05***	–	0.03	5.80***	–
	(0.85)	(5.60)		(0.61)	(0.60)		(0.04)	(0.31)		(0.05)	(0.52)	
Pigovian subsidy	0.19***	0.86***	–	0.18***	0.20***	–	0.01***	0.08***	–	0.03***	1.87***	–
	(0.05)	(0.23)		(0.02)	(0.02)		(0.005)	(0.04)		(0.01)	(0.18)	
Neutral price change	0.36***	1.71***	–	0.25***	0.26***	–	0.003	0.09***	–	0.04***	1.89***	–
	(0.06)	(0.52)		(0.02)	(0.02)		(0.005)	(0.04)		(0.01)	(0.27)	
Attribute 1	0.82***	3.42***	7.80***	0.24***	0.25***	0.11***	0.43	2.27	12.49***	2.68***	110.18***	115.98
	(0.39)	(1.34)	(2.52)	(0.01)	(0.02)	(0.04)	(0.36)	(1.71)	(4.33)	(0.55)	(4.09)	(0.00)
Attribute 2	0.001	0.004	0.001	–	–	–	-0.02***	-0.04***	0.07***	0.002	0.00	0.03***
	(0.002)	(0.004)	(0.004)				(0.005)	(0.02)	(0.03)	(0.004)	(0.01)	(0.01)
Attribute 3	1.54***	3.34***	3.32***	–	–	–	2.50***	−4.34	15.95***	0.01***	0.02***	0.00*
	(0.21)	(0.77)	(0.80)				(0.52)	(4.45)	(7.02)	(0.003)	(0.01)	(0.00)
Attribute 4	−0.64***	−2.67***	5.62***	–	–	–	−1.79***	−9.30***	6.12***	0.24***	0.47***	0.02
	(0.18)	(0.97)	(1.39)				(0.36)	(4.07)	(2.93)	(0.10)	(0.17)	(0.02)
Attribute 5	−1.63***	−7.38***	6.69***	–	–	–	0.23	-4.20*	8.34***	−19.07***	−45.72***	3.39
	(0.25)	(1.96)	(1.54)				(0.29)	(2.38)	(2.96)	(5.50)	(16.28)	(7.32)
Attribute 6	–	–	–	–	–	–	−3.29***	−11.92***	24.06***	0.29***	0.73***	0.53***
							(0.70)	(5.41)	(8.95)	(0.10)	(0.24)	(0.19)
Attribute 7	–	–	–	–	–	–	0.11***	0.66***	0.17***	–	–	–
							(0.02)	(0.23)	(0.08)			
Attribute 8	–	–	–	–	–	–	1.28***	5.38***	8.43***	–	–	–
							(0.25)	(2.22)	(3.36)			
Respondents	148	148		372	372		182	182		152	152	
Log Pseudo-LL	−611.3	−496.5		−882.5	−880.9		−753.5	-538.9		−453.9	−359.9	
AIC	1239.5	1019.0		1773.0	1771.8		1529.0	1115.7		925.9	747.2	
BIC	1262.6	1058.0		1788.7	1791.4		1564.3	1176.6		953.1	790.2	
Pseudo R^2	0.195	0.346		0.144	0.146		0.137	0.383		0.233	0.392	

Notes: This table reports preference parameters estimates for MNL and MXL specifications. For MXL models we estimate both the mean and standard-deviation (std-dev.) of normally distributed preference parameters. Sample size for each product category is twice the number of respondent (every respondent makes two choices). Standard errors are clustered at the respondent level and reported in parenthesis. ***, **, *: statistically significant at 1, 5 and 10 percent respectively. The list of attributes for each product is in Table 2.

Results - Substitutability

Table 6
Substitutability between clean and dirty alternatives: Simulated change in market share of clean alternatives.

	Cola	Milk	Spread	Meat
Neutral price change: CATE	42.10***	11.27***	11.07***	8.52***
	(2.52)	(0.61)	(3.04)	(3.43)
10% neutral price change	70.06***	14.96***	4.46***	10.92***
	(4.13)	(0.63)	(1.23)	(4.52)
Neutral price change (GBP cent)	9.02***	1.84***	0.25***	0.45***
	(0.75)	(0.13)	(0.09)	(0.16)
Respondents	148	372	182	152

Notes: This table displays the marginal impact of the neutrally framed price change on simulated choice probabilities (or market shares) of clean alternatives, reported in percentage points difference. We report changes in simulated choice probabilities corresponding to the conditional average treatment effect (CATE), a 10% price reduction, and a 1 GBP cent price reduction. Simulated choice probabilities are derived from the MXL specifications reported in Table 5. Bootstrapped standard errors clustered at the respondent level reported in parenthesis. ***, **, *: statistically significant at 1, 5 and 10 percent respectively.

Results - Treatment

Table 7
Effectiveness of policy instruments within and across products: Simulated change in market share of clean alternatives.

	Cola	Milk	Spread	Meat
Panel A: Within product comparison				
Information label: CATE	27.00***	12.23***	29.45***	13.78*
	(1.52)	(1.03)	(9.17)	(6.99)
Pigovian subsidy: CATE	21.82***	8.63***	8.47***	8.59***
	(1.24)	(0.72)	(2.48)	(2.89)
Panel B: Across product comparison				
10% information label	5.43***	5.68***	3.19**	1.52*
	(0.74)	(0.63)	(1.34)	(0.82)
Information label ($kgCO_2$)	48.23***	19.70***	2.69***	0.93***
	(2.04)	(0.54)	(0.89)	(0.34)
10% Pigovian subsidy	59.96***	12.01***	3.47***	10.47***
	(1.90)	(0.82)	(0.87)	(2.34)
Pigovian subsidy (GBP cent)	4.46***	1.37***	0.20***	0.45***
	(0.18)	(0.13)	(0.04)	(0.03)
Respondents	148	372	182	152

Notes: Panel A displays the marginal impact of the information treatment and Pigovian subsidy on simulated choice probabilities (or market shares) of clean alternatives, reported in percentage points differences. We report changes in simulated choice probabilities corresponding to the conditional average treatment effect (CATE). Panel B displays the same but for a normalized treatment size representing a 10% difference (in relative emissions or relative prices) or a unit difference (in $kgCO_2$ and GBP cent for the information label and Pigovian subsidy respectively). Simulated choice probabilities are derived from the MXL specifications reported in Table 5. Bootstrapped standard errors reported in parenthesis. ***, **, *: statistically significant at 1, 5 and 10 percent respectively.

Results - EPMs

Table 8
EPM for information and the behavioral effect of Pigovian regulation.

	Cola	Milk	Spread	Meat
Panel A: Equivalent price metric for information (EPM^{info})				
$\Delta e\beta^{info}/\beta^{price}$ (GBP cent)	3.07**	6.61***	128.25**	33.76***
	(1.47)	(1.12)	(53.8)	(3.19)
$\beta^{info}/\beta^{price}$ (GBP per tCO_2)	59.08**	165.15***	114.26**	30.69***
	(28.35)	(28.07)	(47.93)	(11.19)
Panel B: Equivalent price metric for behavioral impact of Pigovian regulation (EPM^{regul})				
$\beta^{regul}/\beta^{price}$ (GBP cent)	−2.50***	−1.50**	−6.82	−0.25
	(0.68)	(0.72)	(15.77)	(1.93)
$\beta^{regul}/\beta^{price}\frac{1}{\Delta e}$ (GBP per tCO_2)	−48.06***	−37.46**	−6.07	−0.22
	(13.14)	(17.92)	(14.05)	(1.76)
Respondents	148	372	182	152

Notes: Panel A displays the equivalent price metric (EPM) for the information label measured in GBP cent (i.e. the EPM of the CATE) and in GBP per tCO_2 (allowing a comparison across product categories). Panel B displays the EPM for the behavioral effect of Pigovian regulation measured in GBP cent (referring to the CATE) and in GBP per tCO_2 (allowing a comparison across product categories). See Table 3 for a definition of the EPM statistics. All estimates are derived from the MXL specifications reported in Table 5. Standard errors clustered at the respondent level obtained via the delta methods reported in parenthesis. ***, **, *: statistically significant at 1, 5 and 10 percent respectively.

Conclusion

Consumer valuation of product carbon emissions > Pigovian pricing (£19 per tCO_2)

Negative behavioral effect from Pigovian regulation

$\Rightarrow$ Compensation is negative

$\Rightarrow$ Pigovian pricing needs to be increased

Intrinsic motivation to behave prosocially (consuming clean goods) is present

Pigovian intervention to enforce prosocial behavior reduces consumer effort

Conclusion

But there's a catch...

Consumers are shown to value carbon emissions more than Pigovian pricing

$\Rightarrow$ Lower Pigovian pricing may signal decreased carbon emission effect

In the case that Pigovian pricing relieves moral cost of harmful behavior

$\Rightarrow$ Increasing Pigovian pricing may induce further harmful behavior due to consumers paying the moral cost