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Essays on Environmental and Resource Economics

by

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Committee in charge:

Professor Peter Berck, Chair
Professor Sofia Berto Villas-Boas
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Abstract

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This dissertation consists of three applied essays on environmental and resource economics. The essays study consumer and local government responses to exogenous shocks: randomized environmental messages, variation in international mineral prices and a widely publicized food–borne disease outbreak. I study these issues both in developing countries (Brazil and Peru) and in developed countries (the United States). In particular, this dissertation focuses in three broad areas: (i) investigating whether environmental messages can increase energy efficient technology adoption by poor populations and understanding the characteristics of the individuals who respond to these messages, (ii) testing whether increases in municipal income translate into additional environmental investments and policies in developing countries and, (iii) studying the role of food borne disease outbreaks on consumer purchases and preferences.

In Chapter 1, "Do Environmental Messages Work on the Poor? Experimental Evidence from Brazilian Favelas," I explore whether environmental messages can be used to induce environmental behaviors in developing countries. In developed countries, the combined use of monetary and non-monetary incentives, such as subsidies and social norms, has been shown to encourage the adoption of energy–saving technologies and conservation behaviors. However, little is known about the effect of these approaches in developing countries, which account for most of the growth in energy demand and greenhouse gas emissions. Using a randomized experiment conducted in 18 favelas (shantytowns) in Rio de Janeiro, Brazil, this first essay investigates the interplay between three levels of monetary incentives and an environmental persuasion communication on the take–up of an energy efficient light bulb (a light emitting diode or, LED). On average, the persuasive communication significantly increases LED take–up by 6–percentage points (a 12.5% increase). This effect is driven by a 13–percentage point (19%) increase in take–up at the middle price. Richer participants, females, and subjects with middle levels of environmental preferences respond the most to the communication. Having some high school education or an energy efficient light bulb at home increases the probability of take–up, irrespective of the communication. I find similar results in a comparable laboratory experiment with UC Berkeley students and staff.

In Chapter 2, "Environmental Investments and Income: A Municipal Perspective," I use detailed panel data on the universe of municipalities in Peru to study whether municipalities undertake more environmental investments when their income increases. I test whether municipalities invest more in green spaces, water treatment, environmental management, waste collection and programs that incentivize environmental protection. Using variation in international mineral prices to generate exogenous variation in municipal income, I find evidence of significant effects of an increase in municipal income on some environmental investments. In particular, municipalities invest more in green spaces, water treatment, municipal waste plans, and frequency of waste collection. However, the magnitude of the effects is relatively small given the large increase in income. I also test whether municipalities invest more in non–environmental investments when their income increases and find evidence of additional investments in education, health and transportation.

In Chapter 3, "Food Borne Disease Outbreaks, Consumer Purchases and Product Preferences: The Case of the 2010 Salmonella Egg Outbreak in the U.S.," joint work with Sofia Berto Villas–Boas, we examine how consumers in California reacted to three consecutive egg recalls during the 2010 Salmonella outbreak. Eggs infected with Salmonella were recalled through codes clearly labeled in egg boxes, leaving no infected eggs in stores. Using a large product-level scanner data set from a national grocery chain, we test whether consumers reduced egg purchases. Using a difference–in–difference approach, we find a 9 percent reduction in egg sales in California following the three egg recalls. Given an overall price elasticity for eggs in U.S. households of -0.1, this sales reduction is comparable to an almost 100% increase in price. We find no evidence of substitution toward other "greener" type of eggs, such as organic or cage free eggs. We also find no correlation with demographics such as income, but we do find that areas that had a larger than average household size decreased egg purchases more. We also find differentiated effects among Northern and Southern Californian stores. Although the national grocery chain had infected eggs only in Northern California, we find that Southern Californian stores had lower egg sales as well. The sales reduction in Southern California was half as large as the reduction in Northern California, and is consistent with media and reputation effects being significant determinants of demand, even in the absence of an actual food infection occurring in a region.

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Chapter 1

Do Environmental Messages Work on the Poor ? Experimental Evidence from Brazilian Favelas[1]

[1]I am very grateful to my advisors Peter Berck and Sofia Berto Villas-Boas for their encouragement and invaluable guidance. I am also indebted to Meredith Fowlie for her constant support and advice. I would like to thank Lydia Ashton, Maximilian Auffhammer, François Gerard, Larry Karp, Leslie Martin, Edward Miguel, Valentina Paredes, Charles Séguin, Renato Seixas and Anna Spurlock for excellent comments. Participants at the Environment and Resource Economics Seminar at UC Berkeley, the BERC Energy Symposium and the Symposium on Economic Experiments in Developing Countries (SEEDEC) provided many valuable suggestions. Financial support from the Institute of Business and Economic Research (IBER) and an X Lab Grant are greatly appreciated. All errors are my own.

1.1 Introduction

The world's poor and near-poor will play a major role in driving medium-run growth in energy consumption.[2] Energy efficient technologies such as efficient lighting, appliances, or cooling provide substantial energy savings and reduce pollution. They can also be used to limit energy consumption growth in developing countries with its potential consequences for climate change. Despite these benefits, energy efficient technologies have been under-adopted. For example, the adoption of energy efficient light bulbs (EELBs) has been limited, even though engineering estimates show that they last longer than conventional (incandescent) light bulbs, consume less energy and are cheaper in the medium run. To encourage the adoption of these technologies,[3] monetary approaches such as subsidies and rebates are commonly used. In addition to these pecuniary incentives, non-monetary approaches such as environmental information[4] and social norms[5] have also been shown to encourage the adoption of energy efficient technologies in developed countries. Prices and non-monetary approaches may work together or at different levels, depending on the targeted good and on the type of consumer. For example, consumers may respond more to non-monetary approaches if they have a relatively inelastic demand or have high levels of environmental preferences. One low-cost non-pecuniary approach for increasing take-up might be the use of tailored environmental messages at the time of purchase. When faced with environmental messages that combine environmental information with descriptive and normative appeals, people may learn about the private and public benefits of the technology, respond to the appeal, and adopt the product. In developing countries, environmental messages are used in different settings, but there is little evidence of the effect of the combined use of monetary and non-monetary approaches. In this paper, I investigate the interplay between monetary incentives and a particular form of persuasive communication on the take-up of energy efficient light bulbs, light-emitting diodes (LEDs), by a poor population in a developing country. While LEDs are more energy efficient than both incandescent light bulbs (ILBs) and compact fluorescent lights (CFLs), their adoption has been very limited in the residential sector due to a high up-front cost.

[2] Wolfram, Shelef and Gertler (2012) find that as low-income households buy their first durable appliances and vehicles, energy growth along the extensive margin will become an important driver of the demand for energy in the near future. EIA (2010) and OECD (2008) discuss the importance of energy consumption of non-OECD countries by 2030, in particular with respect to population growth, urbanization and changing life styles.

[3] Some potential barriers to the adoption of low-cost, energy efficient technologies are the quality, fit or durability of the energy efficient good, imperfect information, uncertainty about energy prices, principal-agent problems, the size of the benefits compared to transactions costs, credit constraints and bounded rationality of consumers.

[4] For example, environmental information approaches can give information on avoided greenhouse gas emissions or water and energy savings.

[5] Social norms refer to rules that govern society's behaviors. In this context, social norms are descriptive social norms that are used to potentially influence the decision to purchase a particular technology or to adopt an environmental behavior. Two possible channels are conformity motivations or the updating of prior beliefs about a technology.

Using data from a randomized experiment that I designed and conducted in street intersections in 18 favelas (shantytowns) in Rio de Janeiro, Brazil, I study the effect of three different monetary incentives and a particular form of persuasive communication on the adoption of LEDs. The environmental persuasion communication uses insights from the psychology literature applied to messages to protect the environment (Cialdini, 2003) and aligns injunctive norms,[6] descriptive norms[7] and environmental information.[8] In this experiment, I ask participants to choose between an incandescent light bulb and an LED. In order to estimate the effect of the environmental persuasion communication on LED adoption, I randomly assign individuals into three LED prices (R$0[9], R$11 and R$16)[10] and into whether they receive the environmental persuasion communication or not.[11] Before the price and environmental communication randomizations, all participants are surveyed and receive technical information that describes and compares energy efficiency, energy costs, and technical differences among ILBs, CFLs, and LEDs. The experimental design allows me to identify the effect of price and of the environmental persuasion communication on LED take-up, to provide new estimates of the price elasticity of demand for EELBs for a poor population in a developing country, and to measure the price equivalence of the effect of the environmental persuasion communication. I also present evidence of heterogeneous effects by analyzing the individual or household (HH) characteristics that make individuals more responsive to the communication as well as those that increase take-up irrespective of the communication. I then compare my results in Brazilian favelas to a very similar experiment undertaken with UC Berkeley students and staff. In this study, I seek to shed light on whether poverty affects the interplay between monetary and non-monetary incentives to adopt energy efficient technologies.

I find that the environmental persuasion communication increases LED take-up by 6 percentage points (a 12.5% increase) on average.[12] However, the environmental communication works differently at each price level. At R$0, take-up is almost perfect and

[6] Injunctive norms involve perceptions of which behaviors are typically approved or disapproved. They help an individual determine what is an acceptable or an unacceptable social behavior. This behavior could be the morals of the individual's interpersonal network and community.

[7] Descriptive norms involve perceptions of which behaviors are typically performed. They usually refer to the perception of others' behavior and are based on the observations of those around the individual.

[8] As shown in Cialdini (2003), environmental messages that mobilize action against a problem by depicting it as regrettably frequent may considerably decrease the persuasiveness of the communication. For example, saying that polluters are damaging the environment carries the undercutting message that many people are already polluting and that it may acceptable to do so. Aligning descriptive norms with injunctive norms optimizes the power of normative appeals.

[9] It was necessary to randomize a price of R$0 in order to eliminate any differences that did not come from price. Examples of such differences are differences in taste for the design of the light bulb or an aversion to adopting a new technology.

[10] In July 2012 the exchange rate was 1 U.S Dollar = R$2 (Brazilian Reais).

[11] Because the market price of the LED was R$22, the randomized prices correspond to a 100%, 50% and 27% subsidy, respectively.

[12] Without any controls, the average probability of LED take-up without the environmental persuasive communication is 0.44 and with the communication it is 0.50.

there is no room for the communication to have an effect. At R$16, it has no significant effect. At the price of R$11, the environmental persuasion communication increases take-up by 13 percentage points (a 19% increase).[13] A possible interpretation of this result is that the environmental communication increases the value of the LED, but it does so conditional on the price being sufficiently low[14] and only to people who are receptive to environmental arguments.[15] Using price and environmental persuasion communication randomizations, I estimate a monetary value of the effect of the communication. For this population and based on the mean take-up at R$11 and R$16, a decrease in price from R$16 to R$11 increases take-up by 62 percentage points, whereas the environmental communication increases take-up by 13 percentage points. The effect of the environmental persuasive communication is equivalent to 21% of the subsidy.[16]

Interestingly, this effect is similar in magnitude to the effect of non-pecuniary approaches used in developed countries to increase the adoption of energy efficient technologies or environmental behaviors such as water or energy conservation.[17] I also find a large effect of an increase in price: increasing the price of the LED from R$0 to R$11 decreases take-up by 26 percentage points and increasing the price from R$0 to R$16 decreases take-up by another 62 percentage points. Given an overall take-up of 70% at the price of R$11 and a 8% take-up at the price of R$16, I find an overall price elasticity of demand of -1.96, showing that LEDs are an elastic good for favela residents.

[13]At R$11 and without any controls, the average probability of LED take-up without the environmental persuasive communication is 0.63 and with the communication it is 0.75. With controls, the probability increases from 12 percentage points to 13 percentage points.

[14]R$11 represents 0.7% of the average HH's monthly income and 1.7% of the poorest segment's monthly income.

[15]Following the same argument, at a price of R$0, every receptive individual has already chosen the LED over the ILB so there is no room for an effect. At R$16, the extra benefit that the communication provides to receptive people is not enough to overcome the difference in price. Finally, at R$11 the difference in price is such that some receptive people do not choose the LED, but can be convinced by the communication because the price difference is low enough.

[16]In other words, conditional on a pre-existing 27% subsidy (used to decrease price from R$22 to R$16), providing an additional 22% subsidy (used to decrease price from R$16 to R$11) increases take-up by 62 percentage points, whereas the environmental persuasive communication increases take-up by 13 percentage points.

[17]Herberich, List and Price (2011) test the effect of social norms on CFL adoption and find a monetary value for social norms in the range of 30%-70% of the CFL market price ($5). Ferraro and Price (2011) find that pro-social messages and social comparisons decrease water consumption by 4.8% and that the effect is equivalent to a 12%-15% increase in price (given a price elasticity of demand of -0.33 to -0.36). Studies related to energy consumption also find significant effects of non-pecuniary approaches. Allcott (2011) finds an effect of social norms equivalent to that of a short-run electricity price increase of 11% to 20% and Ayres, Raseman and Shih (2009) find a decrease in energy consumption from 1.2% to 2.1% with a decrease sustained over time (seven and twelve months) following peer comparisons. Schultz et al. (2007) show that providing social norms decreases energy use by 2%-3%, with effects continuing over time. Goldstein, Cialdini and Griskevicius (2008) study the effect of different descriptive norm statements with environmental motivations on towel re-use in hotel rooms in the United States. The authors find that using descriptive norms in messages was more effective than using only messages that focused on environmental protection.

The effect of the environmental persuasion communication and its magnitude may depend not only on price levels, but also on the characteristics of individuals. Using an individual level survey, I am able to isolate the individual or HH characteristics that make individuals more responsive to the environmental communication as well as those that affect overall LED take-up. I find that richer participants respond more to the persuasive communication, showing a difference in the efficacy of the communication across participants. Consistent with previous literature (Ferraro and Price (2011), Mansur and Olmstead (2007)), there is heterogeneity in the effectiveness of the environmental persuasion communication among participants as richer HH tend to have a more inelastic demand. This suggests that non-pecuniary approaches are most useful as a complement to price measures because they affect subjects who are least sensitive to price changes. I also show that females and participants who have middle levels of environmental preferences respond more to the environmental communication. Participants having some or a complete high school education and the ones that already have an EELB at home have a higher probability of take-up, irrespective of the environmental persuasion communication. Being poor decreases the probability of LED take-up significantly.

I find comparable results in a similar laboratory experiment with students and staff from the University of California at Berkeley. As in the Brazilian experiment, I randomize three different monetary incentives (here \$0, \$2 and \$4) and an environmental persuasion communication that combines environmental information, descriptive norms and injunctive norms. Although not significant at the overall level, results suggest that, on average, the environmental communication increases the probability of LED take-up by 7 percentage points. The communication has no significant effect at the price of \$0 or \$2 but at the price of \$4 it increases the probability of picking the LED over the ILB by around 18 percentage points.[18] I also find that participants in this experiment have a more inelastic demand than those in the Brazilian experiment. Increasing the price of the LED from \$0 to \$2 decreases take-up by 46 percentage points and increasing the price from \$0 to \$4 decreases take-up by another 16 percentage points. This translates into a price elasticity of demand of -0.31, showing that LEDs are a relatively inelastic good over this price range and for this population.

The findings of this paper show that, conditional on offering the energy efficient technology at an affordable price, environmental persuasion communications are a low-cost way of increasing take-up. At the relevant price, the magnitude of the effect is large and compares to other non-pecuniary approaches such as environmental information and social norms. Moreover, this research shows that environmental persuasion communications do have an effect on poor populations, in that all but the poorest segment of the favela population responds. In addition, focusing on locations that have large female populations may increase the effect of the communication. Environmental education programs or environmental campaigns that seek to raise awareness about environmental problems

[18] At a price of \$4 and without demographic controls, LED take-up is 27% without the environmental persuasive communication and 47% with the communication. With demographic controls, the effect decreases from 20 percentage points to 18 percentage points.

such as global warming may also increase the response to future environmental messages. Further, the donation of energy efficient light bulbs can have long term effects because people who already have a (donated) energy efficient light bulb at home are more likely to take-up another energy efficient light bulb.

This paper contributes to the existing literature in the following ways. First, this research contributes to the empirical evidence on the effects of persuasive communications. Although the effects of persuasive communications have been shown in different settings (Bertrand, Karlan, Mullainathan, Shafir and Zinman (2010), DellaVigna and Kaplan (2007), Gentzkow and Shapiro (2010), Falk (2007), Landry, Lange, List, Price and Rupp (2006)), this paper estimates the previously unexplored causal effect of a particular type of environmental persuasion communication on the take-up of an energy efficient technology by a poor population.

Second, this study provides insights on the factors that influence the adoption of energy efficient technologies. While energy efficient technology adoption has been studied in developed countries (Jaffe and Stavins (1994), Costa and Kahn (2010), Davis (2010), Gallagher and Muehlegger (2011)) and in developing countries (Bhattacharya and Cropper (2010), Davis, Fuchs and Gertler (2012) and Wolfram, Shelef and Gertler (2012)), there is little experimental evidence on the individual or household characteristics that make individuals more likely to adopt an energy efficient technology in developing countries.

Third, this paper contributes to the growing experimental evidence of non-pecuniary approaches used to increase energy efficient technology adoption or environmental behaviors (Cialdini (2003), Cialdini et al. (2006), Schultz et al. (2007), Goldstein, Cialdini and Griskevicius (2008), Ayres, Raseman and Shih (2009), Allcott (2011) [b], Ferraro and Price (2011) and Herberich, List and Price (2011)). Economists and psychologists have used experimental approaches to solve the issues of correlated unobservables and have found that the results vary importantly with the product and setting. This paper uses a randomized experiment to analyze the interplay between monetary incentives and an environmental persuasion communication on energy efficient technology adoption by a poor and infrequently studied population in a developing country. In a setting of low levels of income and general education, my results show that environmental persuasion communications can improve take-up significantly.

In the next section, I describe the background of this study. Section 3 explains the experimental design and discusses the data used for the empirical analysis. Section 4 presents the results and section 5 concludes.

1.2 Background

In this section, I provide a brief background on the setting in which this experiment took place. First, I briefly describe favelas, the recent pacification process and electricity consumption in pacified favelas. Second, I explain how LEDs are different from other light bulbs such as ILBs and CFLs. Finally, I discuss the usage of environmental messages in developed countries and in Brazil.

1.2.1 Electricity Consumption and Energy Efficient Appliances in Pacified Favelas

Favelas are Brazilian shanty towns. Initially (toward the end of the 18th century), favelas were the place where former or freed slaves lived. By the 1970s, favelas were the destination of migrants from rural areas of Brazil. By 2010, 6% of the Brazilian population lived in favelas (11 million inhabitants). In Rio de Janeiro, 20% of the population lives in favelas (1 million inhabitants). Favela populations are on average poorer than the average Brazilian population, have lower access to basic infrastructure and are or have been exposed to continuous levels of illegality and violence.[19] In recent years, some favelas have been "pacified". A pacified favela is a favela where the army took control from drug dealers or private militia. The term "pacification" is a translation from the Portuguese "pacificação" and refers to a four step process. First, BOPE (a special force unit of the Military Police of Rio de Janeiro State) and the armed forces enter the favela and take some territories. In a second phase, BOPE and the armed forces undertake a stabilization process and ensure the possession of the territory. In a third phase, a Pacifying Police Unit (UPP) ensures the definitive occupation of the favela by the police. Finally, in a fourth "post occupation" phase, UPP Social undertakes a series of urban, social and economic programs that seek to fully integrate the pacified favela. The eighteen favelas where this experiment took place are pacified favelas. They are at different stages of this pacification process, but they are all in at least phase two.

According to the 2010 Census, electricity provision is 99.9% in pacified favelas in Rio de Janeiro. Energy payment in favelas in Rio de Janeiro represents an important share of the poorest household's income.[20] The residential price of electricity in Rio de Janeiro varies by income area. For example, the average electricity price per kWh in favelas is R$0.23 whereas the average price per kWh for non-low income areas is R$0.34. Table 1.1 shows the price of electricity per kilowatt-hour by income level and also by consumption level for low-income residential consumers in Rio de Janeiro. Lighting accounts for 11% of residential electricity consumption in Brazil. Other major appliances are refrigerators, electric showers and air-conditioning (with 33%, 20% and 10% of electricity consumption, respectively).

Despite differential pricing, favelas still have high levels of clandestine connections ("gato"). In pacified favelas in Rio de Janeiro, clandestine connections are usually the result of either voluntarily using a cable to access electricity without fully paying for it or

[19]Zaluar (2001), Machado Da Silva and Leite (2007) and Barenboim and Campante (2008) discuss the illegality and violence situation in favelas and their effects on several outcomes.

[20]ESMAP (2006) studies the energy needs of the favela Caju in Rio de Janeiro and breaks up households into 4 categories (A,B,C and D). The authors of this study find that the richest segment (A) devotes 2.7% of its income to energy, the next richest (B) spends 5.3%, the next group (C) pays 7.4% and the poorest segment (D) spends 14%.

living in an area that does not yet have meters installed. Favelas or areas within favelas that were pacified earlier tend to have more meters than the ones that were pacified later.[21] According to the 2010 Census, 28% of households in pacified favelas in Rio de Janeiro (as of July 2012) did not have a meter.[22]

To promote the rational use of energy and improve energy efficiency in appliances, the Brazilian government established several energy efficiency programs.[23] Low-income communities have targeted energy efficiency programs. Energy efficiency programs for poor populations include the substitution of inefficient domestic appliances (such as light bulbs, refrigerators or electric showers) and, the promotion of educational activities that stimulate efficient energy consumption, fight electricity theft and promote the normalization of clandestine consumers. Programs also support philanthropic institutions and businesses located inside low-income communities if 50% of the investment is paid by the recipient.

1.2.2 Light Emitting Diodes and Technical Differences With Other Light Bulbs

LEDs are the most efficient light bulbs available. They last longer, consume less energy and cost less to operate than both ILBs and CFLs.[24] Figure 1.1 summarizes most of the technical differences between ILBs, CFLs, and LEDs. This table was also shown and read to all participants in the experiment.[25] As shown in figure 1.1, LEDs last 40 times longer than ILBs, consume 10 times less energy and cost 10 times less to operate. However, they also have a significantly higher up-front cost. For equivalent levels of brightness, LEDs cost 14.6 times more than an ILB and 2.4 times more than a CFL.[26] Given the operating costs shown in figure 1.1, it would take 13 years to recover the investment of purchasing an LED instead of a CFL. However, this assumes that electricity prices and the number of hours of usage stay constant. It also assumes that LED prices do

[21]One of the first entities to enter pacified favelas after the army was the utility company.

[22]In our sample, 32% of participants declare having an illegal connection. Mimmi and Ecer (2010) find that 23% of households interviewed in 12 favelas in Belo Horizonte have illegal connections.

[23]For example, the PROCEL (National Program for Energy Conservation) Stamp is an award given to the most efficient appliances. The ENCE (National Label of Energy Conservation) is a label that gives information on the efficiency level of a specific product and also grades the appliance between A (most efficient) and G (least efficient).

[24]ILBs are the most common and least expensive light bulb to buy. However, because of their relative inefficiency and short life spans, they are usually more expensive to operate. CFLs are more energy efficient and provide a similar amount and quality of lighting but are more expensive. CFLs contain mercury while LEDs do not.

[25]The only information not given to participants in the experiment was the actual market price of the light bulbs. This information was intentionally omitted in order to increase the likelihood that participants pick the LED because of its characteristics and not because it is a valuable good.

[26]In July 2012, there were no subsidies for light bulbs in Brazil. In the United States, some utilities provide instant in-store rebates (up to 50% of the market price) for qualified CFLs. A few pilot programs have given rebates for LEDs but rebates for LEDs are not widespread.

not continue decreasing.[27] In addition to being more energy efficient and having lower operating costs, LEDs have other technical differences that make them more attractive than ILBs and CFLs. For example, as opposed to ILBs and CFLs, LEDs are not sensitive to temperature or humidity, they are not affected by on/off cycling and they are very durable. For society, the advantages of LEDs over ILBs and CFLs include greater energy savings, landfill reductions, the elimination of toxic materials and decreased Greenhouse Gas (GHG) emissions.

The diffusion of EELBs has led to a transformation of the way information is given on light bulb packaging, creating an old way of labeling bulbs (watts) and a new way (lumens). Watts measure the amount of power a bulb uses, not how bright it is.[28] Lumens measure the total “amount” of visible light emitted by a source. The more lumens in a light bulb, the brighter the light. Lumens is a more accurate measurement of brightness that allows comparisons across light bulb types. Table 1.2 shows a watt-lumens conversion chart.[29]

Because ILBs use more energy than energy efficient lamps, many governments have introduced measures to ban their use by setting minimum efficacy standards. Several countries[30] have either banned (regionally or federally) traditional ILBs during the 2010-2014 period or substantially increased their minimum efficiency requirements. In Brazil, the elimination of traditional ILBs is gradual and deadlines vary by watts and lumens/watt.[31] According to the National Program for Energy Conservation (PROCEL), if all ILBs in use in the residential sector were replaced by CFLs at once, savings would be of 5.5 billion of kWh/year. For comparison purposes, this reduction is equivalent to the yearly electricity consumption of the Brazilian Federal District with a population of 2.5 million inhabitants.

1.2.3 Environmental Messages

Many businesses in developed countries commonly use environmental messages to promote some of their initiatives. For example, some commercial banks use environmental messages that encourage online statements and payments to save paper, hotels ask customers to re-use their towels or sheets to save water, and paper towel dispensers in bathrooms have signs that say “these come from trees”. In Brazil, environmental messages

[27] In the United States, LED prices have gone down by more than half in the last five years.

[28] The U.S. Department of Energy makes the comparison that “using watts to describe brightness is like using gallons of fuel to describe how fast a car can go.”

[29] For example, if a consumer is looking for a bulb that will give the amount of light she used to get from a 60-watt bulb, she will now look for 800 lumens.

[30] Countries that have either banned (regionally or federally) traditional ILBs during the 2010-2014 period or substantially increased their minimum efficiency requirements include China, India, the EU members, Canada, the United States, Cuba, Argentina, Venezuela, Brazil and Australia, among others.

[31] By 2016, ILBs should not be produced in or imported into Brazil. Manufacturers and importers have six months after the respective deadlines to sell the products that do not comply with the minimal standards. Stores have one year.

are used to encourage some environmental behaviors. For example, the Brazilian Ministry of the Environment (MMA) encouraged several campaigns that used environmental messages to reduce plastic bag usage ("plastic bags bother" or "saco é um saco"), to encourage recycling ("separate the garbage, hit the can" or "separe o lixo, acerta na lata") and to promote sustainable tourism ("green passport" or "passaporte verde"). Environmental messages are also used to promote public transportation ("whoever takes the train arrives faster and preserves the environment" or "quem vai de trem chega mais rápido e preserva o meio ambiente"). Environmental messages may or may not be persuasive. Research has shown that the wording (Goldstein, Cialdini and Griskevicius (2008)) and images (Bertrand, Karlan, Mullainathan, Sharif and Zinman (2010)) used in these messages can have substantial impacts on the outcome of interest.

1.3 Experimental Design and the Data

I estimate the effect of an environmental persuasive communication on LED take-up by conducting an experiment. An experimental approach allows me to overcome the identification challenges present in other approaches. In particular, an experiment helps address the issues of selection bias by eliminating the bias in the persuasive communication assignment. Selection bias would be a potential concern if this study was undertaken, for example, in stores ("greener" individuals would be more exposed to the communication) or through surveys. This experimental design also eliminates hypothetical bias by making participants choose between an ILB and an LED. Thus, we have a measure of revealed preference for LEDs.

1.3.1 Set Up and Data Collection

During the month of July 2012, 377 residents from 18 different pacified favelas in Rio de Janeiro were surveyed in street intersections. The experiment consisted of price and environmental persuasion communication[32] randomizations. Specifically, I use a 3 by 2 between-subjects experiment to identify the effect of price and of an environmental persuasive communication on LED take-up. Participants choose between an ILB and an LED[33] but may have to "purchase" the LED. The prices at which the LED was offered were R$0, R$11 and R$16. These prices correspond to a 100%, 50% and 27% subsidy respectively as the market price of the LED was R$22. Several pilots also tested potential LED prices of R$3, R$6 and R$8 but, because take-up was almost perfect at those prices, the main experiment used the higher prices of R$11 and R$16. The number of participants

[32] Following DellaVigna and Gentzkow (2010), I define the persuasive communication as "a message provided by one agent (a sender) with at least a potential interest in changing the behavior of another agent (a receiver)."

[33] The experiment made participants choose between an ILB and an LED instead of between a CFL and an LED because 100% of participants have been exposed at least once to an ILB whereas not everyone has been exposed to a CFL.

surveyed in each favela was proportional to the favela's population. Figure 1.2 shows a map of the geographical location of the experimental sites. Surveyed favelas are spread across Rio de Janeiro and have substantial variation in terms of size, population and pacification phases.

To identify the effect on LED take-up of the interplay between monetary incentives and the environmental persuasion communication, I randomly assigned participants to one of six experimental groups.[34] Everyone was offered the choice between a free ILB and an LED whose price was R$0, R$11 or R$16. All participants received technical information on the differences between ILBs, CFLs and LEDs (for example, differences in electricity consumption, annual operating costs and life span) and a compensation for participating (R$11). The price of R$16 had two components: if assigned to this price group, participants had to give up R$11 of their participation compensation and had to pay an additional R$5 to obtain an LED.

Table 1.3 summarizes the experimental groups in this experiment. Participants assigned to group 1 were offered the choice between a free ILB and an LED that "costs" R$0. This means that they obtain whichever light bulb they pick plus R$11 for participating. The purpose of this group is to control for any differences between the two light bulbs (such as differences in taste for the design of the light bulb or an aversion to adopting a new technology) that do not come from price. Participants assigned to group 2 were under a similar set up but now the LED was offered at R$11 instead of R$0 (the ILB was still offered for free). If the participant picks the ILB, she receives R$11 plus the light bulb. If she picks the LED, she receives R$0 for participating and takes the LED. Participants assigned to group 3 were offered the LED at R$16 instead of R$0. If the participant picks the ILB, she receives R$11 plus the light bulb. If she picks the LED, she receives R$0 for participating and has to pay an additional R$5 from her own money to obtain the LED. The purpose of this treatment is to get an additional price level and it is also used to compute a price elasticity of demand for LEDs. Participants assigned to groups 4, 5 and 6 were first given an environmental persuasion communication (EPC) on the positive environmental externalities of using LEDs. Then, participants assigned to group 4 were offered the LED for R$0, participants assigned to group 5 were offered the LED for R$11 and participants assigned to group 6 were offered the LED for R$16.

Enumerators were instructed not to advocate for either type of light bulb and to say that they did not know the actual market price of the light bulbs if asked.[35] Only favela residents that were passing by street intersections were interviewed; those who explicitly asked to be interviewed were not allowed to participate. A typical intervention

[34] Randomization was undertaken everyday before the fieldwork and achieved by labeling enumerators' questionnaires with an experimental group number. Experimental groups were evenly distributed among enumerators and labeled such that the enumerator himself did not know the experimental group until he reached the section for the environmental persuasion communication and the light bulb offer. All questionnaires were used each day.

[35] The box for the light bulb was also torn and discarded. These measures were undertaken in order to minimize the possibility of LED resale.

(including both the survey and the experiment components) lasted around fifteen minutes per person. Participants had to be the person (or one of the persons) responsible for light bulb purchases in the household and only adults aged between 18 and 65 years old were allowed to participate.[36]

First, participants were approached at street intersections[37] and asked if they would like to participate in a study for a university in the United States.[38] Participants were then surveyed and asked whether they are the member of the HH responsible for light bulb purchases (or one of the responsible members), whether they live in the favela where they are being interviewed, their age, how important environmental problems such as global warming are to them, what type of light bulb they have at home[39] and whether they pay for the electricity they consume.[40]

Second, all participants were given technical information on the differences between ILBs, CFLs and LEDs. The information on CFLs was given for comparison purposes only as CFLS were not offered in the experiment.[41] The technical information given consisted of information on energy efficiency and energy costs (average life span, watts of electricity used, annual operating cost) and on other technical differences (sensitivity to temperature, sensitivity to humidity, on/off cycling, turning off and durability). Pictures of the three types of light bulbs were shown to all participants. No information on the mercury content of CFLs was given so as to not confound this information with the environmental communication. Figure 1.1 shows the technical information that was given to all participants before the price and environmental persuasion communication randomizations.

Third, participants randomly assigned to groups 4, 5 or 6 were provided with an addi-

[36]Participants were filtered on whether they were the person (or one of the persons) responsible for light bulb purchases and age because this is commonly done on studies on technology adoption. In particular, marketing research targets the decision makers in the HH as they are the potential buyers.

[37]Seventy-three percent of individuals who were intercepted accepted to participate in the experiment.

[38]At this stage, no information on the participation compensation was given.

[39]Participants were shown pictures of ILBs, CFLs and LEDs and asked to point to the pictures of the light bulbs they have at home. They could point to more than one type as long as they had at least one of each.

[40]Participants were asked if they (or someone in their HH) fully pay for the electricity they consume, partially pay for the electricity they consume or do not pay for the electricity they consume. Note that paying for the electricity consumed is not the same as paying the electricity bill, as some participants may fully pay an electricity bill but, because of an illegal connection, not fully pay for the electricity consumed. Questions were asked verbally but the answers were written down in a large font on a paper so that participants could give their answer verbally or by simply pointing to the place in the paper where the answer was written, without having to explicitly say it. Explanations given for the partial or no electricity payment are that the electricity is shared with a neighbor, that someone who is not a member of the HH pays for the electricity, that the favela has just been pacified and that the utility company has not yet started billing consumers or that the electricity is taken from the street and not registered by the utility company.

[41]Because 62% of participants have at least one CFL at home and only 2% have an LED, including information on CFLs could provide a reference point for some participants.

tional persuasive communication.[42] Using insights from the psychology literature applied to messages to protect the environment (Cialdini, 2003), this form of persuasion communication aligns injunctive norms, descriptive norms and environmental information. First, the environmental persuasion communication informs participants about the threats of global warming to Brazil and the world. Then, it uses injunctive norms by telling participants that there are several ways individuals can limit their impact on the environment, among which is the use of LEDs. Later, the communication gives information on the carbon dioxide emissions[43] that are avoided by using LEDs. Next, the communication uses descriptive norms by informing participants that "thousands of carioca[44] households" already use LEDs. Finally, participants are told that "by replacing one ILB by an LED light bulb in your home, you will contribute to the fight against global warming." The environmental persuasive communication was also accompanied by several images that complemented its content.[45] The environmental persuasive communication used the word "carioca" to create identification by describing a group behavior that occurred in a setting that closely matched participants' immediate surroundings. Figure 1.4 shows the environmental persuasion communication that was read[46] and shown to participants by the enumerators.

Fourth, all participants were given information on the differences between the two proposed light bulbs. The information about the specific ILB and LED offered included brightness (in lumens),[47] estimated yearly energy cost, life in hours and years, light ap-

[42]The environmental persuasion communication said "Global warming will have many negative consequences for both Brazil and the world. To name just a few, temperature increases caused by global warming will create flooding, an increase in the amount of infectious diseases such as dengue, lead to the extinction of many ecosystems and will impact agriculture through droughts. One of the main causes of global warming is the increase of emissions coming from human activities. There are several measures each individual can take to try to limit their impact on the environment. One of them is as simple as changing our light bulbs. LED light bulbs use 80% less energy than incandescent light bulbs. By decreasing the amount of energy produced by power plants, they reduce by 5 to 10 times the amount of carbon dioxide emitted into the atmosphere. If every Brazilian household replaced one ILB with an LED light bulb, we'd save enough power to light more than 3 million homes for a year! Thousands of "carioca" households already use LED light bulbs. By replacing one ILB by an LED light bulb in your home, you will contribute to the fight against global warming."

[43]Although around 80% of Brazil's electricity is generated by hydropower, marginal producers can be fossil fuel power plants. McKinsey (2010) studies the Brazilian power generation matrix under base case scenarios and with abatement policies until the year 2030. The study shows that if specific abatement policies are not undertaken the power generation matrix will become more dependent on fossil fuels in the next 20 years.

[44]Cariocas are inhabitants of the city of Rio de Janeiro.

[45]The communication used a large image that illustrated the consequences of global warming as well as three smaller images with pictures of a favela, persons holding a globe and typical favela trees within the base of a light bulb.

[46]Participants could read along or just listen to the enumerator. Around 9% of participants were illiterate or had at most three years of primary education so these participants received the communication only by listening to the enumerator.

[47]Lumens information is not mandatory in Brazil but was added to this technical description in order

pearance, energy used, type of base, and whether the light bulb emits heat. Figure 1.5 shows the light bulbs offered in this experiment as well as the technical differences between these two specific light bulbs.

Fifth, immediately after this description, participants were offered the LED at R$0, R$11 or R$16 and asked to choose between either an ILB or an LED. After the choice was made, participants were asked to give the reasons for their light bulb choice.

Sixth, participants were surveyed again and asked about their individual and household characteristics, including gender, education level, household size and household income.[48]

Finally, participants were given the light bulb of their choice and given a payment (if any).

1.3.2 Descriptive Statistics

Table 1.4 summarizes responses to the survey. Sixty percent[49] of respondents are female, they are 38 years old on average and more than half of them did not reach the first year of high school. The average household size is 3.7 members and 17% of participants are "poor" where poor is defined (among this already poor population) as having a HH income of one minimum wage or less.[50] Most of the respondents are familiar with energy efficient light bulbs as 63% of them have at least one at home.[51] Around 32% of the households do not fully pay for the electricity they consume. Most participants rate environmental problems such as global warming as very important. Fifty-five percent of participants received the environmental persuasion communication, as slightly more than half of subjects were randomized to groups 4, 5 and 6.[52] Comparing means in this experiment with values obtained from the 2010 Demographic Census undertaken by the Brazilian Institute of Geography and Statistics (IBGE) for the same population, I find that this sample is fairly representative of the pacified favelas population in Rio de Janeiro.[53]

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to facilitate the comparison of both light bulbs. In the United States, manufacturers are required to provide lumens and energy cost information on packaging within a detailed "Lighting Facts" label.

[48]The survey was conducted in two halves so that the questions on education, HH size and income came after the participant was familiar with the enumerator.

[49]This is probably a consequence of having only participants that are the HH member (or one of them) responsible for light bulb purchases in the HH.

[50]In Brazil, income is usually measured in minimum wage brackets. Having a HH wage equal to one minimum wage (311 USD per month) or less was used as a definition of "poor" because this population did not have much income variation. The average HH income was around 2 minimum wages.

[51]Only 2% of participants have an LED at home. The large share of participants that have at least one CFL at home is probably due to the information and CFL donation campaigns undertaken in Brazil after the 2001 electricity crisis.

[52]This was done in order to increase power for the identification of possible heterogeneous effects.

[53]This experiment was undertaken, proportionally to population, in 18 of the 21 favelas in Rio de Janeiro that were pacified (as of July 2012). The 2010 Demographic Census undertaken for this population shows a comparable age of the HH head (40 years old vs. 38 years old for the person -or one of the persons- responsible for light bulb purchases), similar average illiteracy rates (7% vs. 8.75% of illiterates or

1.3.3 Comparison of Means Between Treatment and Control Groups

To assess covariate balance, and given relatively small sample size, I proceed by comparing the means of the overall reference group (experimental group 1) and the other groups. I estimate the following regression for each variable used in the estimation:

$$X_{ij} = \alpha + \beta Price11_{ij} + \gamma Price16_{ij} + \lambda EPC_{ij} + \delta_e + \eta_j + \varepsilon_{ij} \tag{1.1}$$

where X_{ij} is a set of individual or household characteristics, $Price11_{ij}$ is an indicator variable for whether individual i living in favela j was offered the LED at R$11, $Price16_{ij}$ is an indicator variable for whether i living in j was offered the LED at R$16, λEPC_{ij} is an indicator variable for whether i received the environmental persuasion communication, δ_e includes enumerator fixed effects, η_j includes favela fixed effects and ϵ_{ij} is a random error term. Table 1.5 shows the results. In most cases, means are not statistically different across groups. However, two variables have statistically different means across groups: the indicator variable on whether the HH fully pays for the electricity it consumes has statistically different means at the price of R$16 and also under the environmental persuasion communication (both significant at the 10% level), and the variable that rates how important environmental problems such as global warming are to participant also has a statistically different mean at R$16 (significant at the 1% level). Due to the nature of the experiment (random and spontaneous interviews at street intersections) and the relatively small sample size of the reference group, it was impossible to stratify on all the variables.[54]

However, when the effect of the environmental persuasion communication is estimated at the price of R$11, the control group becomes the group that was offered the LED at R$11 but did not receive the environmental communication. The control and treatment groups at R$11 have statistically indistinguishable means as shown by table 1.5.

participants that have at most three years of primary school for our sample), and a similar HH size (3.14 vs 3.69 in our sample). The same census also finds that, in 2010, 28% of HHs in this population did not have a meter that measures their electricity consumption. In our sample taken in July 2012, 32% of HHs do not fully pay for the electricity they consume. Most of the favelas in the sample were pacified in 2011, pacification may have possibly affected income and/or the share of participants that fully pay for the electricity they consume.

[54]These differences in means show that participants randomly assigned to price R$16 and those that received the environmental persuasion communication are less likely than the reference group to fully pay for the electricity they consume. Also, compared to the reference group, participants assigned to price R$16 are less likely to think that environmental problems such as global warming are important. Thus, these differences in means would most likely play against an effect of the environmental persuasion communication on LED take-up since, as shown in the results section, poorer participants and participants with lower levels of environmental preferences respond less to the communication.

1.3.4 Identification Strategy

The analysis uses the following linear probability model (LPM):

$$Takeup_{ij} = \alpha + \beta EPC_{ij} + \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \varepsilon_{ij} \tag{1.2}$$

where $Takeup_{ij}$ equals unity if individual i living in favela j chooses the LED and 0 if she chooses the ILB, EPC_{ij} is an indicator variable that equals unity if individual i living in favela j receives the environmental persuasion communication and 0 otherwise, γ_{pij} are indicator variables for each price group (R\$0, R\$11 or R\$16) and equal unity if i was offered the LED at that price and 0 otherwise, X_{ij} includes relevant controls that might affect LED adoption (gender, age education, HH size, poverty status of the HH, whether the individual has an EELB at home, whether the HH fully pays for the electricity it consumes and the importance of environmental problems such as global warming),[55] δ_e includes enumerator fixed effects,[56] η_j includes favela fixed effects and ε_{ij} is a random error term.[57] I also show results of an equivalent logit regression[58] for the average effects and the effects by price level.

1.4 Results of the Brazilian Experiment

1.4.1 Average Effects

I begin by estimating the overall effect of the environmental persuasion communication on LED take-up. Columns (1), (3) and (5) in table 1.6 show the results of a linear probability model and columns (2), (4) and (6) show the results of a logit regression.[59] Take-up is on average 47.7%. Sample size is slightly different between both models because the logit regression drops observations from favelas that did not have variation in LED take-up (i.e. the favelas that had either perfect take-up or where no one adopted the LED). Columns (1) and (2) test the effect of the environmental persuasion communication controlling for only favela and enumerator fixed effects. Columns (3) and (4) add price controls and columns (5) and (6) include additional demographic controls. Columns (1) and (2) suggest that without any price or demographic controls, the environmental persuasion communication increases the probability of LED take-up by around 6 percentage

[55]In principle, due to randomization, these demographic controls are not needed. However, because some means were found to be statistically different across groups and because I later test for heterogeneous effects, I control for demographic characteristics. Controlling for the variables that have statistically different means across groups assumes linearity.

[56]Enumerator fixed effects control for different abilities enumerators may have in delivering the environmental persuasion communication.

[57]Because the randomization level is the individual (individuals were randomized within favelas), standard errors do not have to be clustered.

[58]The results for the logit regression are average marginal effects.

[59]This is the most restrictive specification that does not allow the effect of the environmental persuasion communication to vary by price.

points but the results are not significant. Column (3) suggests that once price controls are added, the overall effect of the environmental persuasion communication on the probability of LED take-up is still around 6 percentage points but the result is not significant. Column (4) shows that, with price controls and a logit regression, the effect of the environmental persuasion communication is still around 6 percentage points but is significant at the 10% level. Finally, columns (5) and (6) show that, once demographic controls are included, the estimated effect of the environmental persuasion communication on LED take-up is still around 6 percentage points (significant at the 10% level under the LPM and at the 5% level under the logit regression). The estimated effect of an increase in price is large and significant at the 1% level: the LPM presented in column (5) shows that increasing the price of the LED from $R0 to $R11 decreases the probability of take-up by around 26 percentage points and increasing the price of the LED from R$0 to R$16 decreases the probability of take-up by around 87 percentage points. The logit regression in column (6) shows a somewhat different effect of an increase in price. Increasing the price of the LED from $R0 to $R11 decreases the probability of take-up by around 28 percentage points and increasing the price of the LED from R$0 to R$16 decreases the probability of take-up by around 69 percentage points. Being poor and having an EELB at home are the only significant demographic controls. Being a poor HH decreases the probability of LED take-up by around 11 to 13 percentage points, depending on the model, and having an EELB at home increases this probability by 8 percentage points in the logit regression.

1.4.2 Heterogeneous Effects by Price Levels

Figure 1.3 shows the share of LED take-up by price and by whether subjects received the environmental persuasion communication (solid line) or not (dashed line).[60] The figure shows that, at R$0, take-up is 0.96 and there is no room for the environmental communication to have an effect. At R$16, there seems to be no effect of the environmental persuasion communication.[61] At R$11 and without any controls, the environmental persuasion communication increases LED take-up by around 12 percentage points. The confidence intervals shown in the graph are the confidence intervals from the regression at R$11 without any controls. At a price of R$11, the average LED take-up is 70%, while at R$16, the average LED take-up is 8%. Therefore, the price elasticity of demand of moving from a price of R$11 to a price of R$16 is [(0.08-0.70)/0.70]/[(16-11)/11] =-1.96, showing that LEDs are an elastic good over this price range and for this population.

Given the results observed in figure 1.3, I estimate the effect of the environmental persuasion communication at a price of R$11. Table 1.7 presents the results with data only from participants that were offered the LED at R$11. Columns (1) and (3) show

[60] This figure shows the means of each experimental group, two per price level, with a line connecting the means by whether individuals received the environmental persuasion communication or not.

[61] Take-up is also significantly lower so it could be the case that there is not enough power to identify a possible effect at this price level.

results for an LPM and columns (2) and (4) show results for a logit regression. Without demographic controls and at a price of R$11, the environmental persuasion communication increases the probability of take-up by 12.9 percentage points under the LPM (significant at the 10% level) and by 14.1 percentage points under the logit regression (significant at the 5% level). Columns (3) and (4) include demographic covariates for both the LPM and logit and find very similar results. Table 1.7 also shows that having at least some high school education, as opposed to only primary or middle school education, increases the probability of LED take-up by around 19 or 21 percentage points, depending on the model (significant at the 5% level under the LPM and at the 1% level under the logit regression). Being a poor HH decreases the probability of LED take-up by 22 or 20 percentage points, depending on the model (both significant at the 5% level). Table 1.8 estimates again the effect of the environmental persuasion communication at the price of R$11 using the full dataset and interactions. Results are similar though somewhat smaller. With demographic controls, the effect is 12.9 percentage points with the LPM and 9.3 percentage points with the logit regression. There is no significant effect of the environmental communication at R$16.

1.4.3 Results by Demographics

This section shows the effect of the environmental persuasion communication on LED take-up by individual and HH demographics such as HH poverty status, gender, education, the type of light bulb the participant has at home, whether she fully pays the electricity she consumes and the importance she gives to environmental problems such as global warming. The environmental persuasion communication has no significant effects on LED take-up by age or HH size. Although results were tested with both an LPM and a logit regression, I show results from the LPM only.[62] Table 1.9 shows the effect of the environmental communication by the poverty status of the HH, where a HH is defined as poor if it earns a minimum wage or less (i.e. if it is in the poorest segment of the sample). Column (1) shows results without demographic controls and column (2) shows results with demographic controls. Columns (1) and (2) show that the environmental persuasion communication increases LED take-up of richer individuals by 13 percentage points at the price of R$11 (significant at the 10% level) and by 13.8 percentage points once demographic controls are included (significant at the 5% level). The effect on the poorest seems to be slightly larger than the one on richer individuals but it is not significant. These results suggest that poor populations do respond to environmental persuasion communications on average and that the less poor respond the most. Columns (1) and (2) also show that the effect of an increase in price is larger for the poorest.

Table 1.10 shows the effect of the environmental persuasion communication on LED take-up by gender, where male is the omitted category. Columns (1) and (2) show that,

[62] Due to the several cuts and relative small sample size, the LPM handled the interactions better than the logit regression. Results from the logit regression are available upon request.

at a price of R$11, the total effect of receiving the environmental persuasion communication when the participant is female and has been offered the LED at R$11 is 17.2 percentage points without demographic covariates and 17.8 percentage points with demographic controls (both results are significant at the 10% and 5% level, respectively). The same effect for males is around 1 percentage point and not significant. At R$16 and with demographic controls, the effect on females is only 3.6 percentage points and no longer significant. This suggests that the effect of the environmental persuasion communication on the probability of LED take-up at R$11 is mostly driven by females. The result is large but consistent with previous literature[63] that suggests that females contribute more to public goods.

Table 1.11 shows the results by education level. Once demographic controls are included, the environmental persuasion communication at R$11 seems to increase take-up by 12 percentage points for participants having some or a complete high school education, but the results are not significant. Participants with higher education do not seem to respond more to the environmental communication at the price of R$11, however the sample size is also smaller. Based on the results from table 1.7, this suggests that participants with at least some high school education respond less to the environmental persuasion communication at R$11 because they were already adopting the LED more (compared to participants with some primary or middle school education).

Most regressions show that having an EELB at home increases LED take-up by around 8 percentage points (significant at the 5% or 10% level). This suggests that participants are relatively satisfied with their EELBs, which were possibly donated, and are willing to try another even more efficient light bulb (only 2% of participants declare having at least one LED at home).[64] To test whether participants that already have an EELB at home respond more to the environmental persuasion communication, I estimate two triple interactions between the environmental persuasion communication, having an EELB at home and being offered the LED at R$11 or at R$16. Table 1.12 shows the results. Columns (1) and (2) suggest that participants that have at least one EELB at home, were offered the LED at R$11 and received the environmental talk have a 12% higher probability of taking up the LED. However, the results are not significant. The effect is

[63]Andersen, Bulte, Gneezy and List (2008) find that, compared to patrilineal societies, matrilineal societies have fewer strong free-riders, higher levels of public good provision, and more contributions by men to public goods. Eckel and Grossman (2008) find that women are more socially minded than men in public good games, ultimatum games, and dictator experiments, especially when risk is absent. Croson and Gneezy (2009) review the literature on gender differences in economic experiments and identify robust differences in risk preferences, social (other-regarding) preferences, and competitive preferences. Non-experimental studies find that female voting coincided with immediate increases in state government expenditures and revenue (Lott and Kenny, 1999), that men and women may have different party preferences, especially after divorce (Edlund and Pande, 2001) and that female political leaders invest more in infrastructure that is directly relevant to the needs of their own genders (Chattopadhyay and Duflo, 2004).

[64]Another possible explanation is that participants that have an EELB at home are "greener" and therefore more of them adopt the LED.

substantially smaller and insignificant when the LED is offered at R\$16. Based on the results from table 1.6, this suggests that participants who have an EELB at home are already taking-up the LED more and thus respond less to the environmental persuasion communication.

I then test whether an individual not fully paying for the electricity she consumes is less likely to adopt the LED as compared to another individual who does fully pay. A similar landlord-tenant problem has been discussed in many studies (Jaffe and Stavins (1994), Nadel (2002), Gillingham, Newell and Palmer (2009) and Davis (2012)) that find that landlords may buy cheap inefficient appliances when their tenants pay the utility bill. Davis (2012) shows that, controlling for HH income and other HH characteristics, renters are significantly less likely to have energy efficient refrigerators, washing machines and dishwashers. In this experiment, I exploit variation in the pacification phase across and within favelas to obtain variation in the type of electricity payment. Favelas that were pacified earlier tend to have metering devices installed and subsidized plans for poor households. Favelas that were pacified later tend to be in the process of formalization of electricity provision, while favelas that were most recently pacified (or are in the process of pacification) may still not have meters.[65] Once favelas are pacified, there is within-favela variation in the level of enforcement of electricity payment; households that live in the "highest" (i.e. usually poorest) part of the favela may not pay for their electricity because they have an illegal connection or because the utility company has not yet installed meters in their area. In this sample, 32% of subjects do not fully pay for the electricity they consume. I use this variation to estimate the effect of the environmental persuasion communication by whether the HH fully pays its electricity consumption or not. Table 1.13 shows the results. Columns (1) and (2) suggest that fully paying the electricity bill, receiving the environmental persuasion communication and being offered the LED at R\$11 increases LED take-up by 10 percentage points, but the results are not significant. Tables 1.6 and 1.7 suggest that, irrespective of the environmental persuasion communication, there is a small (2 percentage points) effect on LED take-up of fully paying for the electricity consumed, but the results are not significant. A first possible explanation for this result is that the data is noisy. A second possible explanation is that favela residents who currently do not pay for their electricity expect the utility company to install meters and start billing them soon, because this happened fairly quickly in areas that were pacified earlier, and thus anticipate the full payment of an electricity bill in the short term.[66]

The environmental persuasion communication could have an effect on people who already considered environmental problems important. Kronrod, Grinstein and Wathieu (2012) show that the persuasiveness of assertive language depends on the perceived importance of the issue being discussed.[67] In this experiment, respondents were asked to rate, in

[65]Most of the favelas where this experiment took place were pacified in 2011.

[66]In the survey, some participants said that they live in an area that is "under maintenance" and that the utility was in the process of installing meters.

[67]In four different experiments that relate to various environmental contexts, Kronrod, Grinstein and

a scale from 1 through 7, how important environmental problems such as global warming were to them. From this self-assessed measure, I construct three levels of environmental preferences: "low", "medium" and "high". In this section, I test whether participants responded differently to the environmental persuasion communication depending on their a priori view on the environment. Table 1.14 shows the results. For clarity purposes, double and triple interactions are omitted. Respondents who had middle levels of environmental preferences, were offered the LED at R$11 and received the environmental persuasion communication had a 22.9% higher probability of picking the LED over the ILB. This result is significant at the 5% level without any demographic controls. Once demographic information is included, the effect is 19.9 percentage points (significant at the 10% level). I do not find this effect on participants who have high level of environmental preferences at R$11, or at any level of environmental preferences when the LED is offered at R$16. A regression which interacts having high environmental preferences and being offered the LED at R$11 (regression not shown) suggests that participants that have high level of environmental preferences take-up the LED more and therefore do not respond to the environmental persuasion communication. Thus, participants who would be most likely to respond to the environmental persuasion communication are those who have middle levels of environmental preferences. However, the results are not significant.

1.4.4 Laboratory Experiment with UC Berkeley Students and Staff

As a pilot of the Brazilian study, I conducted another experiment at UC Berkeley during May and June 2012. In total, 209 UC Berkeley students or staff participated in a laboratory experiment in seven different sessions. The experiment was entirely computer-based[68] and, as in the Brazilian experiment, consisted of price and environmental persuasion communication randomizations. The proposed prices for the LED were $0, $2 and $4. These prices correspond to a 100%, 80% and 60% subsidy respectively, as the market price of the LED was $10. In this experiment, UC Berkeley students or staff voluntarily decided to attend the sessions and thus subjects were not necessarily the responsible member of the HH for light bulb purchases, or one of the responsible members. Participants received a compensation for participating ($10/ half an hour). The details of this experiment can be found in the appendix. Table 1.15 summarizes the experimental groups used in this experiment.

All participants were given almost the same technical information as in the Brazilian

Wathieu (2012) find that recipients respond better to pushy requests in domains that they view as important, but they need more suggestive appeals when they lack initial conviction.

[68]This experiment provides an additional channel through which the environmental persuasion communication is delivered. As opposed to the Brazilian experiment where participants could perceive an implicit pressure from the enumerators, this experiment randomly delivered the communication through computers.

experiment.[69] Before the experiment, a brief survey was undertaken and participants were asked questions on their gender, age, years of schooling, income, whether they have an EELB at home, if they fully pay for their electricity and how important environmental problems such as global warming are to them. After the experiment, participants were asked why they chose the selected light bulb.

The environmental persuasion communication was the same as the one used for the Brazilian experiment, the only difference being that participants were told about the threats of global warming to the United States and about LED usage in California households instead of "carioca" households.

All participants were asked to choose between an ILB or an LED and the offer was made after the price and environmental persuasion communication randomizations. Figure 1.8 shows the light bulbs offered in this experiment as well as the technical differences between these two specific light bulbs.

Results from the experiment with UC Berkeley students and staff suggest that the environmental persuasion communication also has an effect on this population. As in the Brazilian experiment, the environmental communication works only at a certain price level. In this experiment, this price level was the highest one ($4). At $0, take-up is almost perfect and there is no room for the environmental persuasion communication to have an effect. At $2, there seems to be no effect of the environmental persuasion communication. At a price of $4 and without any controls, the environmental persuasion communication increases LED take-up by around 20 percentage points. With demographic controls and using the full dataset with interactions, the environmental persuasion communication increases LED take-up by 18 percentage points under an LPM and by 15 percentage points under a logit regression (both significant at the 10% level).

1.4.5 Reasons for Light Bulb Adoption in Both Experiments

After participants selected a light bulb, they were asked to give the reasons why they picked the ILB or the LED. The main reasons why participants pick the ILB are that they do not want to give up their participation compensation and because it is cheaper than the LED. The main reasons why participants choose the LED are that they care about the environment, they like EELBs and that they want to try a new type of light bulb. Figure 1.6 shows the reasons why participants chose the ILB or the LED in the Brazilian experiment and figure 1.7 shows the reasons given in the UC Berkeley experiment. Brazilian subjects seem to place more value than participants in Berkeley on the fact that the ILB is cheaper than the LED, while more participants in Berkeley say that they chose the LED because of environmental concerns.

[69] The only differences were that the electricity prices reflected U.S. national averages ($0.11/kWh), annual operating costs assumed 3 hours of use per day and costs were calculated for the average U.S. household (i.e. for 30 bulbs). In the U.S, costs are typically calculated at the HH level. For the Brazilian experiment, it was unclear how many light bulbs the average HH would have so costs were presented for only one bulb.

1.5 Conclusion

This paper uses a randomized field experiment in favelas in Rio de Janeiro, Brazil to analyze the effect of a particular form of persuasive communication on the take-up of an energy efficient light bulb. I find that receiving the environmental persuasion communication increases the overall probability of LED take-up by 6 percentage points (a 12.5% increase). This effect is driven by a 13 percentage point (19%) increase in the probability of take-up at the middle price. This paper shows that poor populations do respond to environmental persuasion communications because all but the poorest segment of the favela population respond. Richer participants, females and subjects with middle levels of environmental preferences respond more to the environmental persuasion communication. While having some high school education or an energy efficient light bulb at home increases the probability of take-up, being poor decreases this probability, irrespective of the communication. In a comparable experiment with UC Berkeley students and staff, I find similar results.

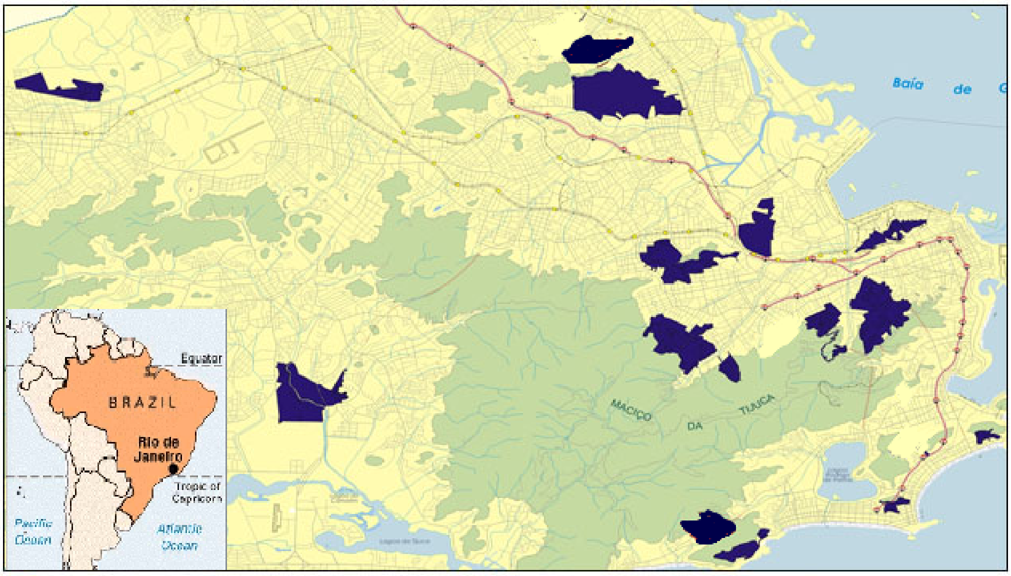
The results presented have the following implications for the design of environmental communications that seek to encourage energy efficient technology adoption. The findings of this paper suggest that, conditional on offering the energy efficient technology at an affordable price, environmental communications are a low-cost way for increasing take-up among poor populations. Because wealthier individuals and females respond more to the environmental communication, focusing on locations that have wealthier or large female populations may increase the effect of the communication. This study also suggests a long term effect of light bulb donations because subjects that already have a (possibly donated) energy efficient light bulb at home are more likely to take-up another energy efficient light bulb. Finally, environmental education programs or environmental campaigns that seek to raise awareness about environmental problems such as global warming may, if properly tailored, have the additional benefit of making recipients more responsive to future environmental communications.

Figure 1.1: Technical Differences Between Light Bulbs

	Incandescent (ILB)	CFL	LED
			
Energy Efficiency & Energy Costs (25 watt eq.)			
Average Life Span (in hours)	750	8000	30000
Watts of Electricity Used	25W	5W-6W	2W-3W
Annual Operating Cost	R$8.4	R$1.8	R$0.8
Light Bulb Price (not shown to participants)	R$1.5	R$9	R$22
For 1 LB, based on 4 hrs/day, R$0.23/kWh. Cost depends on rates and use.			
Other Technical Differences			
Sensitivity to Temp.	Some	Yes	None
Sensitivity to Humidity	Some	Yes	None
On/Off Cycling	Some	Yes	No Effect
Turns Off Instantly	Yes	No	Yes
Durable	Not Very	Not Very	Very

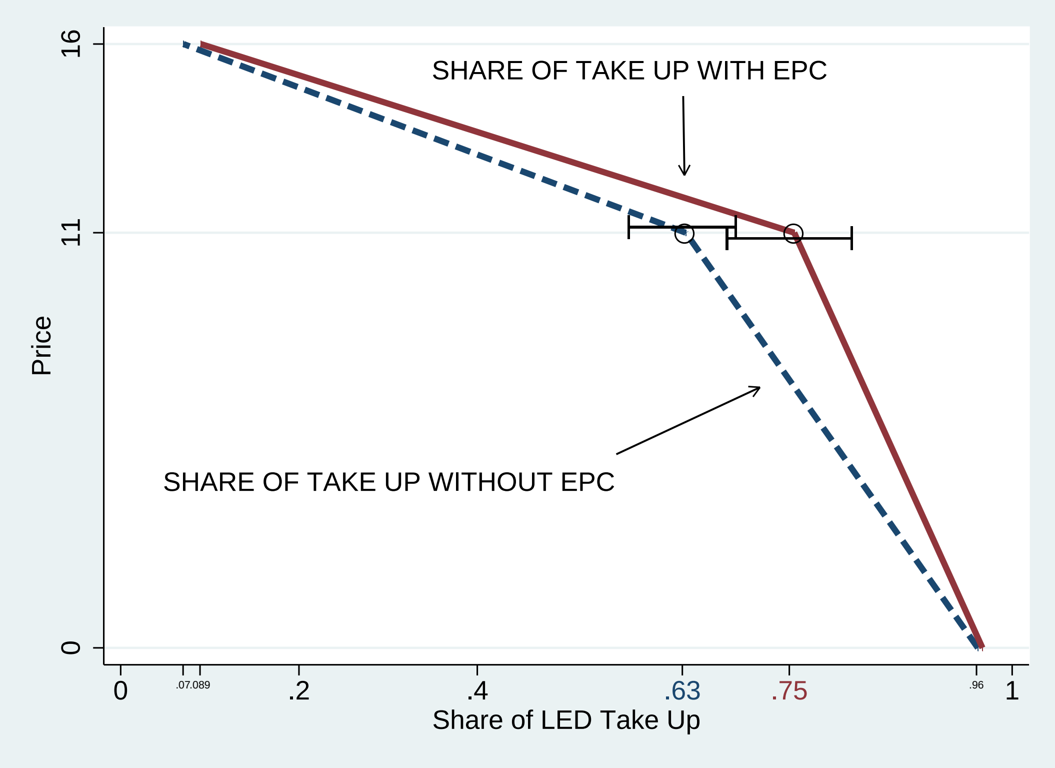
Source: US Department of Energy / Osram, adapted with average Rio de Janeiro favela electricity prices.

Figure 1.2: Geographical Location of Experimental Sites



Source: Adapted from UPP Social.

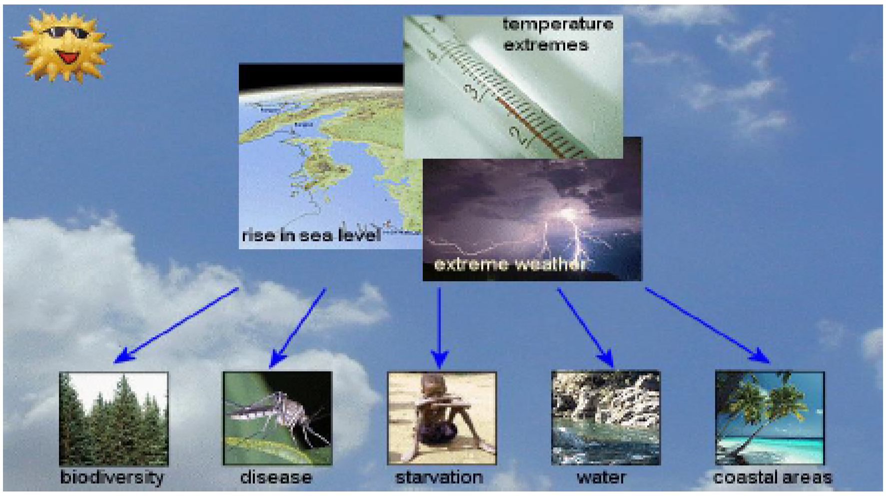
Figure 1.3: Share of LED Take Up by Price and EPC (Brazilian Experiment)



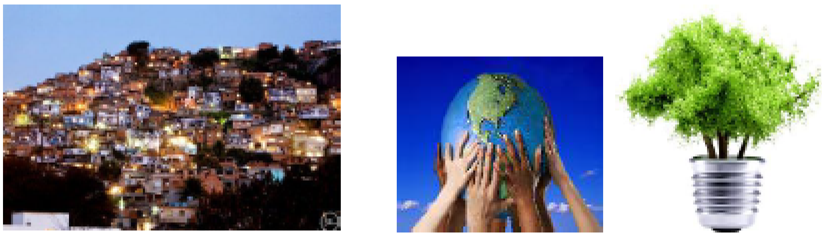
Notes: This graph shows the share of LEDs picked over ILBs by price levels and by whether participants received the environmental persuasion communication (solid line) or not (dashed line). Price levels are R$0, R$11 and R$16. Lines connect means by price groups and by EPC. Confidence intervals are from the corresponding regressions without controls.

Figure 1.4: Environmental Persuasion Communication

Global warming will have many negative consequences for both Brazil and the world. To name just a few, temperature increases caused by global warming will create flooding, an increase in the amount of infectious diseases such as dengue, lead to the extinction of many ecosystems and will impact agriculture through droughts.



One of the main causes of global warming is the increase of emissions coming from human activities. There are several measures each individual can take to try to limit their impact on the environment. One of them is as simple as changing our light bulbs. LED light bulbs use 80% less energy than incandescent light bulbs. By decreasing the amount of energy produced by power plants, they reduce by 5 to 10 times the amount of carbon dioxide emitted into the atmosphere. If every Brazilian household replaced one ILB with a LED light bulb, we'd save enough power to light more than 3 million homes for a year! Thousands of "carioca" households already use LED light bulbs. By replacing one ILB by a LED light bulb in your home, you will contribute to the fight against global warming.



Source (figures): (top), http://mfemfem.wordpress.com/2010/05/22/jr-women (bottom left), http://newearthdaily.com/announcing-the-global-peace-wave/hands-holding-globe (bottom middle) http://www.oficinadasustentabilidade.com.br/index.php?cont=interna-noticias&id_noticia=16 (bottom right)

Figure 1.5: Light Bulb Offer (Brazilian Experiment)

Please choose between:

1) Incandescent Light Bulb

OR

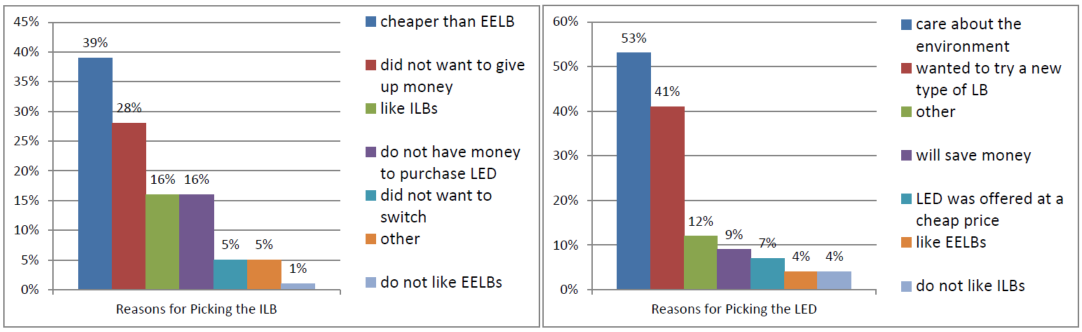
2) LED Light Bulb

The technical differences between these two particular light bulbs are summarized below.

	INCANDESCENT	LED
Brightness (in lumens)	150 to 220 (i.e. the light emitted by these two light bulbs is comparable)	
Estimated Yearly Energy Cost	R$8.39 (Based on 4 hrs/day, R$0.23 /kWh. Cost depends on rates and use)	R$0.73 (Based on 4 hrs/day, R$0.23/kWh. Costs depend on rates and use.)
Life	0.5 years/6months (Based on 4hrs/day)	20 years (Based on 4 hrs/day)
Light Appearance	transparent	white
Energy Used	25 Watts	2.2 Watts
Base	Standard medium base	
Life hours	750	30000
Emits heat/Warms Up	Yes	No

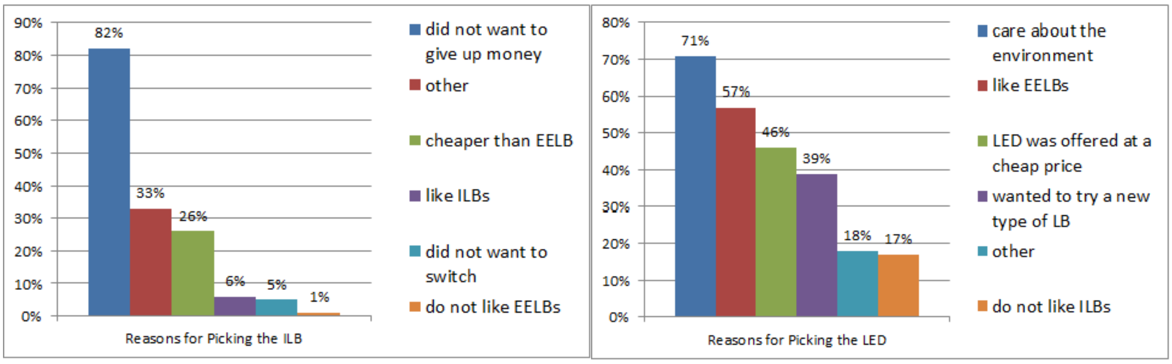
Note: Lumens allow you to compare the light emitted by different types of light bulbs.

Figure 1.6: Reasons for the Light Bulb Choice, ILB (left) or LED (right) in the Brazilian Experiment



Note: Percentages do not add up to 100% because subjects were allowed to choose more than one option.

Figure 1.7: Reasons for the Light Bulb Choice, ILB (left) or LED (right) in the UC Berkeley Experiment



Note: Percentages do not add up to 100% because subjects were allowed to choose more than one option.

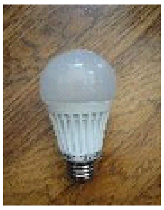
Figure 1.8: Light Bulb Offer (UC Berkeley Experiment)

Please choose between:

1) General Purpose Incandescent Light Bulb

OR

2) General Purpose LED Light Bulb



The technical differences between these two particular light bulbs are summarized below. Please note that this incandescent light bulb is more efficient that a "standard" incandescent light bulb.

	INCANDESCENT	LED
Brightness (in lumens)	410 to 429	
Estimated Yearly Energy Cost	$4.58 (Based on 3 hrs/day, 11¢/kWh. Cost depends on rates and use)	$0.96 (Based on 3 hrs/day, 11¢/kWh. Costs depend on rates and use)
Life	1.8 years (Based on 3hrs/day)	46 years (Based on 3 hrs/day)
Light Appearance	2700 to 3000 K, both white	
Energy Used	38 Watts	8 Watts
Base	Standard bulb shape and medium base	
Life hours	1970	50000

Notes: Estimated yearly energy costs are based on 3 hours/day, 11¢/kWh (cost depends on rates and use). Light bulb "life" assumes 3 hours of use per day. Source: US Department of Energy / Osram.

Table 1.1: Price of Electricity by Income Level and Consumption (Residential) in 2012

Description	Price (R$/kWh)
Residential	0.34304
Residential (Low Income)	
Monthly Consumption $\leq$ 30 kWh	0.11335
30 kWh$<$Monthly Consumption$\leq$ 100 kWh	0.19428
100 kWh$<$Monthly Consumption$\leq$ 220 kWh	0.29143
Monthly Consumption $>$ 220 kWh	0.32381

Source: ANEEL. Prices are in Brazilian Reais per kilowatt-hour. Data are for the company LIGHT.

Table 1.2: Watts- Lumens Conversion Chart

Watts (energy)	150	100	75	60	40
Lumens (brightness)	2600	1600	1100	800	450

Note: Estimates based on a typical incandescent bulb. Source: Federal Trade Commission (FTC).

Table 1.3: Experimental Groups by Price and Environmental Persuasion Communication (Brazilian Experiment)

	No Env. Persuasion Communication	With Env. Persuasion Communication
Price of LED=R$0	Group 1	Group 4
Price of LED=R$11	Group 2	Group 5
Price of LED=R$16	Group 3	Group 6

Table 1.4: Summary Statistics (Brazilian Experiment)

	Obs	Mean	Std. Dev	Min	Max
PANEL A: INDIVIDUAL AND HOUSEHOLD CHARACTERISTICS					
Female	377	0.604	0.489	0	1
Age	377	38.185	12.547	18	65
Primary Educ	377	0.551	0.497	0	1
HS Educ	377	0.395	0.489	0	1
Higher Educ	377	0.053	0.224	0	1
HH Size	377	3.697	1.618	1	9
Poor HH	377	0.169	0.375	0	1
PANEL B: TYPE OF LIGHT BULB AT HOME AND TYPE OF ELECTRICITY PAYMENT					
EELB	377	0.636	0.481	0	1
Fully Pays	377	0.679	0.467	0	1
PANEL C: ENVIRONMENTAL PREFERENCES					
Imp. Env Pbls	377	2.177	0.752	1	3
PANEL D: TREATMENT AND OUTCOME VARIABLES					
EPC	377	0.554	0.497	0	1
LED Take-Up	377	0.477	0.500	0	1
No. of Individuals: 377					
No. of Favelas: 18					

Notes: All participants are the person responsible for light bulb purchases in the household (HH), or one of them. Female is equal to 1 if the interviewee is female and 0 if he is male. Age is the demeaned age in years of the interviewee (18-65 years old only). Primary Educ is a dummy for whether the individual has at most a complete or incomplete primary or middle school education (“analfabeto/até 3a série fundamental”, “4a a 7a série fundamental” or “fundamental completo”), HS Educ is an indicator variable for whether the individual has at most a complete or incomplete high school education (“médio incompleto” or “medio completo”) and Higher Educ is a dummy for whether the participant has at most a complete or incomplete higher education (college or other post-secondary institution). HH size is the demeaned number of people that live in the interviewee’s HH, including the interviewee but excluding any domestic workers. Poor HH is equal to 1 if the HH earns one minimum wage or less (up to R$ 622) and 0 if the HH earns more than one minimum wage. As a reference, in July 2012 the exchange rate was 1 USD = 2 R$. EELB is a dummy for whether the HH has at least one energy efficient light bulb at home (CFL or LED). Fully Pays is a dummy equal to one if the HH pays the entire amount of electricity it consumes and 0 otherwise. Imp. Env Pbls is a self-assessed demeaned measure of how important environmental problems such as global warming are to the participant, where 1=important or less (low preferences), 2= very important (middle preferences) and 3= extremely important (high preferences). EPC is a dummy for whether the individual received the environmental persuasion communication and LED Take-Up is the share of interviewees that chose the LED over the ILB at all price groups.

Table 1.5: Comparison of Means Between Reference and Treatment Groups (Brazilian Experiment)

	Sample Mean	Ref. Group Mean	P=R$11	P=R$16	EPC	Price R$11		
		(P=R$0, no EPC)	T-C	T-C	T-C	Sample Mean	Control	Treat
Female	0.604	0.461	0.107	0.052	0.039	0.645	0.676	-0.041
	(0.489)	(0.508)	(0.077)	(0.077)	(0.050)	(0.479)	(0.471)	(0.077)
Age	38.185	38.269	-0.887	2.059	0.946	36.925	37.070	-0.553
	(12.547)	(11.701)	(1.938)	(1.957)	(1.295)	(12.272)	(11.975)	(1.988)
Primary Educ	0.551	0.500	-0.077	0.010	-0.033	0.503	0.563	-0.104
	(0.497)	(0.509)	(0.078)	(0.078)	(0.050)	(0.501)	(0.499)	(0.078)
HS Educ	0.395	0.461	0.038	-0.027	0.033	0.428	0.380	0.083
	(0.489)	(0.508)	(0.078)	(0.078)	(0.050)	(0.496)	(0.488)	(0.079)
Higher Educ	0.053	0.038	0.039	0.017	0.000	0.068	0.056	0.021
	(0.224)	(0.196)	(0.033)	(0.031)	(0.023)	(0.253)	(0.232)	(0.042)
HH size	3.697	3.615	0.223	0.113	0.081	3.770	3.760	0.031
	(1.618)	(1.416)	(0.254)	(0.248)	(0.167)	(1.674)	(1.642)	(0.265)
Poor HH	0.169	0.076	0.085	0.072	0.019	0.186	0.154	0.051
	(0.375)	(0.271)	(0.058)	(0.058)	(0.037)	(0.390)	(0.364)	(0.061)
EELB	0.636	0.653	-0.004	-0.059	0.002	0.664	0.718	-0.090
	(0.481)	(0.485)	(0.071)	(0.073)	(0.049)	(0.473)	(0.453)	(0.073)
Fully Pays	0.679	0.807	-0.084	-0.106*	-0.083*	0.689	0.661	0.038
	(0.467)	(0.401)	(0.062)	(0.064)	(0.043)	(0.464)	(0.476)	(0.065)
Imp. Env Pbls	2.177	2.500	-0.105	-0.294***	-0.020	2.248	2.239	0.031
	(0.752)	(0.583)	(0.113)	(0.114)	(0.075)	(0.758)	(0.685)	(0.118)
F test of p-value			1.36	1.80	0.84			0.89
Observations	377	26	161	160	209	161	71	90

Left Panel: Sample Mean gives summary statistics for the entire sample. Ref. Group Mean gives summary statistics for the reference group (the group that did not receive an environmental persuasion communication and was offered the LED at R$0), with standard deviations in parentheses. The columns P=R$11, P=R$16 and EPC show differences in means between the treatment group and the reference group, with robust standard errors in parentheses. Right panel: Sample Mean gives summary statistics for the entire sample at R$11. "Control" gives summary statistics for the control group (the group that did not receive the environmental persuasion communication), with standard deviations in parentheses. The column "treatment" shows differences in means between the treatment group (the one that did receive the environmental persuasion communication) and the control group, with robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. All regressions include enumerator and favela fixed effects.

Table 1.6: Effect of the EPC on Overall LED Take-Up

	LED Take Up (1=yes,0=no)					
	LPM	Logit	LPM	Logit	LPM	Logit
	(1)	(2)	(3)	(4)	(5)	(6)
EPC	0.0565	0.0573	0.0595	0.0595*	0.0615*	0.0683**
	(0.0517)	(0.0506)	(0.0362)	(0.0347)	(0.0372)	(0.0344)
Price 11			-0.275***	-0.305***	-0.259***	-0.282***
			(0.0474)	(0.0830)	(0.0485)	(0.0777)
Price 16			-0.894***	-0.722***	-0.868***	-0.691***
			(0.0386)	(0.0701)	(0.0432)	(0.0651)
Female					-0.0109	-0.0216
					(0.0380)	(0.0376)
Age					0.000578	0.000154
					(0.00162)	(0.00155)
HS Educ					0.0709	0.0596
					(0.0438)	(0.0396)
Higher Educ					-0.0372	-0.0573
					(0.0806)	(0.0766)
HH Size					0.00927	0.0119
					(0.0118)	(0.0107)
Poor HH					-0.139**	-0.116**
					(0.0577)	(0.0473)
EELB					0.0662	0.0859**
					(0.0410)	(0.0389)
Fully Pays					0.0255	0.0150
					(0.0468)	(0.0421)
Imp. Env Pbls					0.0311	0.0222
					(0.0276)	(0.0238)
Constant	0.441***		0.961***		0.860***	
	(0.0924)		(0.0751)		(0.0974)	
Observations	377	371	377	371	377	371
R-squared	0.066	0.038	0.545	0.487	0.571	0.529

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Environmental Persuasion Communication (EPC) is a dummy for whether the participant received the environmental persuasion communication and Price 11 (Price 16) is a dummy for whether the participant was offered the LED at R$11 (R$16). The logit regression uses average marginal effects. The LPM and the logit regression have different number of observations because the logit regression drops favelas where there is no variation in LED take-up. All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.7: Effect of the EPC at the Price of R$11

	LED Take Up (1=yes,0=no)			
	LPM	Logit	LPM	Logit
	(1)	(2)	(3)	(4)
EPC	0.129*	0.141**	0.131*	0.140**
	(0.0710)	(0.0689)	(0.0690)	(0.0685)
Female			0.0273	0.0145
			(0.0716)	(0.0823)
Age			-0.000312	0.000436
			(0.00315)	(0.00339)
HS Educ			0.191**	0.211***
			(0.0876)	(0.0793)
Higher Educ			0.0136	0.00424
			(0.146)	(0.148)
HH Size			0.0225	0.0252
			(0.0209)	(0.0230)
Poor HH			-0.228**	-0.201**
			(0.110)	(0.0891)
EELB			0.0908	0.104
			(0.0845)	(0.0824)
Fully Pays			0.0211	0.00618
			(0.0913)	(0.0943)
Imp. Env Pbls			0.0380	0.0390
			(0.0449)	(0.0510)
Constant	0.722***		0.539***	
	(0.111)		(0.148)	
Observations	161	144	161	144
R-squared	0.221	0.126	0.325	0.244

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Data are for participants that were offered the LED at R$11 only. The logit regression uses average marginal effects. The LPM and the logit regression have different number of observations because the logit regression drops favelas where there is no variation in LED take-up. All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.8: Effect of the EPC at a Price of R$11 Using the Full Dataset

	LED Take Up (1=yes,0=no)			
	LPM	Logit	LPM	Logit
	(1)	(2)	(3)	(4)
EPC	0.000944	0.00982	0.0197	0.0329
	(0.0554)	(0.159)	(0.0623)	(0.149)
Price 11	-0.341***	-0.335***	-0.320***	-0.311***
	(0.0693)	(0.116)	(0.0734)	(0.109)
Price 16	-0.903***	-0.722***	-0.860***	-0.673***
	(0.0519)	(0.114)	(0.0586)	(0.105)
Female			-0.00546	-0.0192
			(0.0383)	(0.0376)
Age			0.000700	0.000259
			(0.00162)	(0.00154)
HS Educ			0.0677	0.0566
			(0.0440)	(0.0396)
Higher Educ			-0.0456	-0.0622
			(0.0806)	(0.0764)
HH Size			0.00964	0.0119
			(0.0116)	(0.0108)
Poor HH			-0.145**	-0.121**
			(0.0570)	(0.0478)
EELB			0.0746*	0.0926**
			(0.0409)	(0.0394)
Fully Pays			0.0142	0.00899
			(0.0472)	(0.0427)
Imp. Env Pbls			0.0307	0.0215
			(0.0275)	(0.0239)
Constant	0.995***		0.889***	
	(0.0719)		(0.0934)	
EPC + EPC * Price 11	0.120*	0.075*	0.129*	0.093**
	(0.070)	(0.041)	(0.067)	(0.042)
EPC + EPC * Price 16	0.019	0.026	0.005	0.015
	(0.043)	(0.066)	(0.046)	(0.063)
Observations	377	371	377	371
R-squared	0.548	0.488	0.574	0.531

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The logit regression uses average marginal effects. To avoid clutter, double interactions are not shown. The LPM and the logit regression have different number of observations because the logit regression drops favelas where there is no variation in LED take-up. All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + \gamma_{pij} + EPC_{ij} * Price11_{ij} + EPC_{ij} * Price16_{ij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.9: Effect of the EPC by Poverty Status of the HH (LPM)

	LED Take Up (1=yes,0=no)	
	(1)	(2)
EPC	-0.000250	0.0167
	(0.0596)	(0.0650)
Poor HH	0.0536	0.0679
	(0.0733)	(0.0851)
Price 11	-0.288***	-0.282***
	(0.0740)	(0.0779)
Price 16	-0.908***	-0.882***
	(0.0573)	(0.0613)
Female		-0.00883
		(0.0382)
Age		0.000758
		(0.00162)
HS Educ		0.0577
		(0.0449)
Higher Educ		-0.0629
		(0.0811)
HH Size		0.00778
		(0.0116)
EELB		0.0841**
		(0.0399)
Fully Pays		0.0138
		(0.0475)
Imp. Env Pbls		0.0333
		(0.0274)
Constant	0.965***	0.871***
	(0.0723)	(0.0941)
EPC + EPC * P11	0.130*	0.138**
	(0.071)	(0.070)
EPC+EPC*PoorHH+EPC*P11+EPC*PoorHH*P11	0.165	0.143
	(0.193)	(0.191)
Observations	377	377
R-squared	0.573	0.586

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. A household is defined as poor if it has a monthly wage of one minimum wage or less (up to R$622 ~311 USD). All regressions include enumerator and favela fixed effects. To avoid clutter, double and triple interactions are not shown. “P11” stands for “Price 11.” Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + PoorHH_{ij} + \gamma_{pij} + EPC_{ij} * PoorHH_{ij} + EPC_{ij} * \gamma_{pij} + PoorHH_{ij} * \gamma_{pij} + EPC_{ij} * PoorHH_{ij} * \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.10: Effect of the EPC By Gender of the Subject (LPM)

	LED Take Up (1=yes,0=no)	
	(1)	(2)
EPC	-0.125	-0.108
	(0.0943)	(0.0929)
Female	-0.0967	-0.1000
	(0.0921)	(0.105)
Price 11	-0.324***	-0.318***
	(0.0975)	(0.0956)
Price 16	-0.930***	-0.903***
	(0.0620)	(0.0641)
Age		0.0006
		(0.00165)
HS Educ		0.0700
		(0.0442)
Higher Educ		-0.0512
		(0.0817)
HH Size		0.0088
		(0.0117)
Poor HH		-0.149***
		(0.0566)
EELB		0.0664
		(0.0406)
Fully Pays		0.0123
		(0.0475)
Imp. Env Pbls		0.0309
		(0.0279)
Constant	1.041***	0.939***
	(0.0706)	(0.0879)
EPC+EPC*Female+EPC*P11+EPC*Female*P11	0.172*	0.178**
	(0.088)	(0.084)
EPC+ EPC*P11	0.016	-0.006
	(0.053)	(0.059)
EPC+EPC*Female+EPC*P16+EPC*Female*P16	0.021	0.036
	(0.115)	(0.110)
Observations	377	377
R-squared	0.349	0.579

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. To avoid clutter, double and triple interactions are not shown. "P11" stands for "Price 11" and "P16"stands for "Price 16." All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + Female_{ij} + \gamma_{pij} + EPC_{ij} * Female_{ij} + EPC_{ij} * \gamma_{pij} + Female_{ij} * \gamma_{pij} + EPC_{ij} * Female_{ij} * \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.11: Effect of the EPC by Education Level of the Subject (LPM)

	LED Take Up (1=yes,0=no)	
	(1)	(2)
EPC	-0.0414	-0.0190
	(0.0682)	(0.0726)
Price 11	-0.465***	-0.434***
	(0.0818)	(0.0828)
Price 16	-0.937***	-0.902***
	(0.0465)	(0.0538)
HS Educ	-0.0591	-0.0685
	(0.0907)	(0.0997)
Higher Educ	0.161*	0.160
	(0.0936)	(0.102)
Female		0.0008
		(0.0399)
Age		0.000447
		(0.00161)
HH Size		0.00853
		(0.0118)
Poor HH		-0.146**
		(0.0570)
EELB		0.0739*
		(0.0426)
Fully Pays		0.0163
		(0.0478)
Imp. Env Pbls		0.0308
		(0.0275)
Constant	1.019***	0.934***
	(0.0636)	(0.0853)
EPC+EPC*P11+EPC*HSEduc+EPC*P11*HSEduc	0.092	0.121
	(0.093)	(0.095)
EPC+EPC*P11+EPC*HgEduc+EPC*P11*HgEduc	-0.022	0.033
	(0.265)	(0.266)
Observations	377	377
R-squared	0.570	0.589

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Education levels are some or complete primary or middle school, some or complete high school and some or complete higher education. To avoid clutter, double and triple interactions are not shown. "P11" stands for "Price 11" and "HgEduc" stands for "Higher Educ." All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + i.Educ_{ij} + \gamma_{pij} + EPC_{ij} * i.Educ_{ij} + EPC_{ij} * \gamma_{pij} + i.Educ_{ij} * \gamma_{pij} + EPC_{ij} * i.Educ_{ij} * \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.12: Effect of the EPC by whether the Individual has an EELB at Home (LPM)

	LED Take Up (1=yes, 0= no)	
	(1)	(2)
EPC	-0.137	-0.0812
	(0.126)	(0.126)
EELB	-0.0895	-0.0552
	(0.0803)	(0.0907)
Price 11	-0.527***	-0.451***
	(0.115)	(0.122)
Price 16	-0.972***	-0.898***
	(0.0554)	(0.0681)
Female		-0.00647
		(0.0378)
Age		0.000597
		(0.00161)
HS Educ		0.0660
		(0.0446)
Higher Educ		-0.0396
		(0.0822)
HH Size		0.0106
		(0.0118)
Poor HH		-0.143**
		(0.0577)
Fully Pays		0.00866
		(0.0469)
Imp. Env Pbls		0.0268
		(0.0277)
Constant	1.064***	0.983***
	(0.0672)	(0.0912)
EPC+EPC*EELB+EPC*P11+EPC*EELB*P11	0.115	0.125
	(0.081)	(0.077)
EPC+EPC*EELB+EPC*P16+EPC*EELB*P16	0.066	0.057
	(0.068)	(0.069)
Observations	377	377
R-squared	0.561	0.343

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. In this experiment, energy efficient light bulbs (EELBs) are either CFLs or LEDs. "P11" stands for "Price 11" and "P16" stands for "Price 16." All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + EELB_{ij} + \gamma_{pij} + EPC_{ij} * EELB_{ij} + EPC_{ij} * \gamma_{pij} + EELB_{ij} * \gamma_{pij} + EPC_{ij} * EELB_{ij} * \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.13: Effect of the EPC by the Individual's Type of Electricity Payment (LPM)

	LED Take Up (1=yes,0=no)	
	(1)	(2)
EPC	0.109	0.138
	(0.208)	(0.233)
Fully Pays	0.208	0.163
	(0.185)	(0.212)
Price 11	-0.250	-0.248
	(0.207)	(0.231)
Price 16	-0.733***	-0.720***
	(0.192)	(0.218)
Female		-0.00718
		(0.0386)
Age		0.000871
		(0.00160)
HS Educ		0.0694
		(0.0441)
Higher Educ		-0.0506
		(0.0808)
HH Size		0.00990
		(0.0115)
Poor HH		-0.142**
		(0.0573)
EELB		0.0741*
		(0.0409)
Imp. Env Pbls		0.0313
		(0.0278)
Constant	0.822***	0.769***
	(0.197)	(0.218)
EPC+EPC*FullyPays+EPC*P11+EPC*FullyPays*P11	0.101	0.102
	(0.082)	(0.078)
Observations	377	377
R-squared	0.553	0.577

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. "P11" stands for "Price 11." All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + FullyPays_{ij} + \gamma_{pij} + EPC_{ij} * FullyPays_{ij} + EPC_{ij} * \gamma_{pij} + FullyPays_{ij} * \gamma_{pij} + EPC_{ij} * FullyPays_{ij} * \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.14: Effect of the EPC by the Importance of Environmental Problems (LPM)

	LED Take Up (1=yes,0= no)	
	(1)	(2)
EPC	0.111	0.161
	(0.116)	(0.123)
Middle Env Pref	0.00744	0.0219
	(0.138)	(0.146)
High Env Pref	0.135	0.189
	(0.106)	(0.116)
Price 11	-0.450**	-0.392**
	(0.194)	(0.187)
Price 16	-0.713***	-0.604***
	(0.145)	(0.147)
Female		0.00122
		(0.0387)
Age		0.00100
		(0.00163)
HS Educ		0.0701
		(0.0444)
Higher Educ		-0.0187
		(0.0860)
HH Size		0.0113
		(0.0117)
Poor HH		-0.164***
		(0.0593)
EELB		0.0747*
		(0.0404)
Fully Pays		0.0198
		(0.0472)
Constant	0.915***	0.784***
	(0.121)	(0.137)
EPC+EPC*MEP+EPC*P11+EPC*MEP*P11	0.229**	0.199*
	(0.110)	(0.111)
EPC+EPC*HEP+EPC*P11+EPC*HEP*P11	0.015	0.050
	(0.110)	(0.105)
Observations	377	377
R-squared	0.564	0.592

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. To avoid clutter, double and triple interactions are omitted. “P11” stands for “Price11”, “MEP” stands for “Middle Env Pref” and “HEP” stands for “High Env Pref.” All regressions include enumerator and favela fixed effects. Regression equation: $Takeup_{ij} = \alpha + \beta EPC_{ij} + i.envpref_{ij} + \gamma_{pij} + EPC_{ij} * i.envpref_{ij} + EPC_{ij} * \gamma_{pij} + i.envpref_{ij} * \gamma_{pij} + EPC_{ij} * i.envpref_{ij} * \gamma_{pij} + \lambda X_{ij} + \delta_e + \eta_j + \epsilon_{ij}$.

Table 1.15: Experimental Groups by Price and Environmental Persuasion Communication (UC Berkeley Experiment)

	No Env. Persuasion Communication	With Env. Persuasion Communication
Price of LED=$0	Group 1	Group 4
Price of LED=$2	Group 2	Group 5
Price of LED=$4	Group 3	Group 6

Chapter 2

Environmental Investments and Income: A Municipal Perspective[1]

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2.1 Introduction

After annual Gross Domestic Product (GDP) growth of 6% on average during the 2005-2010 period and several years of high mineral prices, Peruvian municipalities' total income nearly doubled[2] in only six years. Faced with large amounts of additional income, municipalities made investment decisions in various programs. Because most of the growth in energy demand, fossil fuel use, associated local pollution and greenhouse gas emissions will come from developing countries in the coming decades (Wolfram, Shelef and Gertler (2012), EIA (2010), OECD (2008)), the question of whether municipalities invest their additional revenues in environmental investments is relevant for public policy. As the poorest municipalities get richer, we would like to know whether they undertake more environmental investments, whether they may have to be "encouraged,"[3] what is the nature and speed of these investments and what are their priorities. Further, we would like to know if these investments are one-shot investments or if they are part of a trend that will continue over time. Using municipality level data on income and investments, this study seeks to shed light on the nature and magnitude of environmental investments.

Despite the large increase in municipal income, in 2010, only 35% of municipalities treated their water, 11% of municipalities did not collect their waste and 55% of municipalities disposed of their waste in an open dump. Given the paradox of increasing municipal income and low levels of environmental investments, this paper seeks to shed light on the following questions: First, does an increase in municipal income alone lead to more environmental investments? Second, if so, what is the nature and speed of these investments? Finally, in which non-environmental areas are municipalities spending their additional revenues?

First, I show that on average, mining prices do indeed increase mining transfers, which, in turn, increase municipal income (i.e. mining transfers are not crowding out other revenues). Second, allowing a maximum lag-time of three years, I find evidence of positive and significant effects: municipalities invest more in green spaces, water treatments, municipal waste plans, and more frequent waste collection. Third, although there are positive, significant effects on certain environmental investments, the magnitude of these effects is relatively small given the large increase in municipal income. Fourth, I find that increases in municipal income lead to non-environmental municipal investments in areas such as health, education and transportation. Finally, the results suggest that municipalities face significant trade-offs between environmental and non-environmental investments.

The environmental economics literature has studied the relationship between economic development and pollution. In particular, the literature on the Environmental Kuznets Curve (EKC) studies the existence of an inverted U-shape relationship between ambient

[2]The real net municipality income (real income minus the balance from the previous year and minus debt) reported in the RENAMU datasets increased by 88% between the years 2005 and 2010.

[3]Municipalities' environmental investments can be encouraged through minimum standards, tax incentives or information campaigns, for example.

levels of pollution and GDP per capita. This relationship seems to be more associated with local pollutants than with global pollutants (e.g. CO_2) and with developed countries (Xepapadeas (2005)). The EKC has typically been tested in cross-country studies (Shafik and Bandyopadhyay (1992), Harbaugh, Levinson and Wilson (2002), Perman and Stern (2003)), though some papers undertake a within-country analysis (Vincent (1997), Carson et al. (1997)). According to the EKC, in the first stage of industrialization, pollution grows rapidly because people prefer jobs and income to clean air and water. Communities do not have enough income to pay for regulation, enforcement and abatement. The relationship between economic development and pollution becomes an inverted U-relationship as income rises. This is because leading industrial sectors become cleaner and people value the environment more. At this stage, the regulatory institutions become more effective. Finally, starting in the middle income range (usually at a per capita income of $5000 to $8000), pollution levels fall toward pre-industrial levels. The empirical support on the existence of an EKC is mixed, some studies find empirical support for it (Grossmand and Krueger (1995), Carson et al. (1997)) while others do not (Harbaugh, Levinson and Wilson (2002), Perman and Stern (2003)). The discussion also varies with respect to the estimation technique used, the type of pollutant studied, the income level studied and whether countries are developed or not.[4]

The direct impact of resource-based transfers (as opposed to overall municipal income) on municipal-level outcomes has also been studied. For example, Caselli and Michaels (2013) study the impact of municipal oil royalties in Brazil and find no effect of off-shore oil on municipal non-oil GDP or its composition, while on-shore oil has modest effects on non-oil GDP composition. In particular, they find very small or no significant effects on health and sanitation, the percent of the population living in housing with garbage collection, the percent of the population living in housing with piped water or the percent of households receiving water from the main network.

This paper differs from prior literature in three distinct ways. First, this research uses exogenous variation in mineral prices to identify the effect of an increase in municipality income on environmental investments, its magnitude and how it evolves with income and time. Second, this paper provides a within-country analysis in a developing country. Using a panel of municipalities within a developing country provides a finer level of analysis and helps overcome some of the issues associated with previous cross-country studies. Finally, this paper studies a broad set of environmental investments such as investments in green spaces, water treatment, environmental management, waste collection and programs that incentivize environmental protection.

The rest of the paper is organized as follows. Section 2 provides an overview of Peruvian municipalities' income, spending and mining-based transfers and section 3 describes the data. Section 4 discusses the econometric model and section 5 the main results. Section 6 presents results for non-environmental investments as well as a test of the exclusion

[4]A related branch of the literature studies the income elasticity of environmental quality. For example, Kriström and Riera (1996) find that the income elasticity of environmental quality is smaller than one, suggesting that environmental quality is not a luxury good.

restriction. Section 7 concludes.

2.2 Municipality Income and Natural Resource Based Transfers

2.2.1 Municipality Income

Peru is divided into 25 departments;[5] departments are divided into 195 provinces and provinces are divided into 1834 municipalities.[6] Municipalities are the smallest political-administrative subdivision. The government in each municipality is led by a mayor elected for four years. The capital of the province is in a “municipal province.”

Municipalities’ income is broken up into several revenue categories. The revenue categories are taxes, rates, contributions, sale of goods, services provision, canon (resource-based transfers), non-canon property rent, fines and others, other current income, asset sales, loan amortization, other income from capital, transfers and financing. Figure 2.1 shows municipalities’ income by source of revenue for the years 2005 and 2008. From the figure, we can see that municipalities’ source of revenue is diversified and that a growing and significant component of it has been natural resource-based transfers (“canon”), transfers from the central government (mainly FONCOMUN[7]) and the increase in finance (i.e. credit operations and the balance from the previous year). Figure 2.2 shows how municipalities’ income was spent by programs in 2008. Most of the municipal income financed administration (28%), land and transportation programs (20%), sanitation (11%), social and community assistance (8%) and educational infrastructure (6%). Three percent financed programs identified as “environmental protection.”[8]

2.2.2 Mining - Based Transfers

2.2.2.1 Mining in Peru

Mining in Peru contributes to 6% of GDP,[9] 4% of formal labor and 60% of total exports. Peruvian mining exports are diversified and rank highly both in Latin America and the world. Figure 2.3 (a) shows the composition of mining exports by mineral for the

[5]Departments are the equivalent of U.S. states.

[6]The number of provinces and municipalities change over time. The numbers presented here are for the time period of this study.

[7]FONCOMUN is a transfer from the central government to municipalities; it is roughly equal to 2% of sales tax.

[8]Some outcomes referred to as “environmental investments” in this paper can be categorized as “sanitation” by the municipality.

[9]Other sectors contributing to GDP include services (55%), manufacturing (15%) and agriculture (8%).

year 2008. Export destinations include Switzerland, China, the United States, Japan and other European and South American countries.

Mining units are spread across the country so that only three states[10] (mainly Amazonian) out of twenty-five do not receive mining transfers. Figure 2.3 (b) shows a map of the main mining units in the country.

2.2.2.2 Mining Canon

There are 3 types of mining-based transfers: the mining canon, mining royalties and concession fees. Because the mining canon represents 95% of mining-based transfers, I will focus exclusively on this type of transfer. The mining canon is equal to 50% of the income tax that the holders of the mining activity title pay for the exploitation of mineral resources (20% from 1996-2002). The income tax is around 30% and the tax base is net profits. Thus, if there are no profits, there is no canon. The canon is not an additional tax paid by mining firms, it is 50% of what the central government receives as income tax.

Mining units are spread out across the country, as shown in figure 2.3 (b). This translates into cross-sectional variation of mining-transfers within and across states. Figure 2.4 shows the evolution of the mining canon by state, the variation in transfers across states and the aggregated real mining canon from 1998 to 2010. To illustrate the relationship between mining transfers, municipality income and international mineral prices, figure 2.5 shows the evolution of the real net municipality income, the real net municipality spending and the aggregated real mining canon distributed by the central government to the local governments from 2002 to 2010, while figure 2.6 shows the evolution of international mineral prices for the same time period. All mineral prices have 1998 as their base year. We observe from these figures that municipality income, transfers and mineral prices all grow slowly starting in 2003, increase sharply in 2007, and decrease around 2009.

A key point in this analysis is the fact that the mining canon can only be used on capital goods (i.e. investments). Boza Dibos (2006) describes how the canon can be spent by the local governments. Importantly, up to 100% of the transfers can be invested in projects that have regional or local impact, including basic services and development for the community. Similarly, 30% has to go to productive investments for the sustainable development of the communities where the resources are extracted, up to 20% on maintenance of infrastructure that has regional or local impact, up to 20% to finance costs associated with the choice of investments, and finally 1% to finance the profile of the investments that have regional or local impact. In this way, the central government tried to prevent the use of the canon for paying wages and current spending. However, because of these laws, several projects aimed at training municipal employees and strengthening the institutional capacity of regional and local governments have been unable to receive canon funding. Projects over certain amounts have to be approved by the National System of Public Investment (SNIP).

[10] These states receive oil transfers.

The distribution rules have changed several times. The most important changes have been the change in the amount of the income tax redistributed back to local governments (20% from 1997-2002 and 50% thereafter), the inclusion of poverty as a distribution criteria in 2005 (before only population was used), and the amounts received by the producer municipalities, provinces and departments. Note that, when the canon is not used in a particular year, it is saved and can be used in a later year.

In 2008, the mining canon was the most important[11] transfer and represented 40% of all the transfers made by the central government to the local governments. It also represented 22% of the average municipality's revenue.[12] In Peru, the distribution of the mining canon is based on the following rules. First, in order for the mining canon to apply, there needs to be exploitation of metallic or non-metallic mineral resources. Exploration does not generate income tax. Second, mining firms need to be making profits because a firm that does not make profits does not pay income tax and thus no mining canon is distributed. Finally, the distribution of the mining canon depends on the following three factors:

1. Mining firms' profits (which depend on international mineral prices)

2. The population of a municipality (the greater the population of a municipality, the more transfers it receives)

3. The poverty of a municipality (the poorer the municipality, the more transfers it receives)

The following subsections describe in detail how the mining canon is allocated. Profits of mining firms and population of municipalities are self-explanatory, so I will describe only how the poverty of each municipality is measured.

2.2.2.3 The Unsatisfied Basic Needs (UBN) Indicator

The Unsatisfied Basic Needs (UBN) indicator is used as a measure of poverty for each municipality. It is a number from 0 to 1 and is composed of the following indicators:

1. Homes with inappropriate physical characteristics (floor, wall and roof with materials such as mud or straw)

2. Overcrowded houses (three or more people per room)

3. Homes without waste pipes

[11]The second most important transfer was FONCOMUN equal to 31% of all the transfers from the central government to the local governments.

[12]Several countries have resource–based transfers. For example, Brazil, the United States, Venezuela, Norway, Chad, Kuwait and Canada have transfers from oil revenues and Chile has revenues from copper production. See Tsalik (2003) for a review of how these transfers are distributed.

4. Homes with at least one school-aged child who is not going to school
5. Homes with high economic burdens or economic dependence (the household head has not finished elementary school and has 3 or more people per income earner)

The indicator is a percentage of the population or homes that have one or more unsatisfied needs. Each municipality has a UBN indicator that varies over time.[13] The higher the UBN, the poorer the municipality. Note that, until July 2005, the distribution of the mining canon was based exclusively on mining firms' income tax and population of the municipalities. Due to concerns about several municipalities that had high levels of poverty but small populations, the mining canon law was modified to include the UBN.

2.2.2.4 The Mining Canon Distribution Formula

The mining canon is distributed in the following manner. First, the government distributes 50% of what it receives as income tax back to the local governments. Of this 50%, 10% will go to the "producer" municipality, the municipality where the mine is physically located (if the mine is in two municipalities, then this amount is split in two equal portions), 25% to the municipalities that are in the province where the producer municipality is located, 40% to the municipalities that are in the state of the producer municipality and 25% to the state government. Figure 2.7 illustrates how the mining canon is distributed among local governments. The UBN and population criteria are used to distribute transfers among the municipalities that are in the producer province and the producer state. The producer municipality always[14] receives at least 10% of the transfer and the state government always receives 25%. By law, 20% of the amount transferred to the state government has to fund public universities in the state. Finally, the following formulas describe the distribution of the mining canon for the municipalities in the producer province and state.

1. Municipality j as a member of a producer province:

$$\frac{Population_{municipality} * UBN_{municipality}}{\sum(Population_{ofeachmunicipalityintheprovince} * UBN_{ofeachmunicipalitytintheprovince})} \tag{2.1}$$

2. Municipality j as a member of a producer state:

$$\frac{Population_{municipality} * UBN_{municipality}}{\sum(Population_{ofeachmunicipalityinthestate} * UBN_{ofeachmunicipalityinthestate})} \tag{2.2}$$

[13] For several years, the government did not update these numbers. They are updated only when a new census or particular survey is undertaken. The same goes for population numbers per municipality.

[14] The law has changed several times. Sometimes the producer municipality is also included in the producer province and producer state calculations. Currently, the producer municipality is included in these calculations and thus receives transfers three times (once as a producer municipality, once as a member of the producer province and once as a member of the producer state). Over the entire time period of the study, the producer municipality received at least 10%.

Formula (1) determines how much is allocated to each municipality member of the producer province and formula (2) how much is allocated to each municipality member of the producer state. Both formulas calculate the ratio of the municipality's population times the UBN indicator over the sum of the population of each municipality in the province or state, times the UBN indicator of each municipality in the province or state. The higher these ratios are, the more transfers the municipality receives.

2.2.2.5 Timing of the Mining Canon

From 1997 to 2006, the mining canon followed a specific distribution timing. Figure 2.8 illustrates this timing. First, mining firms pay in advance (monthly) their income tax in year 1. Then, in April of year 2, the taxing authority (SUNAT) verifies the income tax paid by mining firms. In year 2 the budgets of the local governments are determined on projections of what firms should pay for their income tax. The true amount is usually higher. In July of year 2, the central government transfers the mining canon to the local governments in twelve monthly payments until June of year 3. The timing for the years 2007 and 2008 was different than the previous years. Transfers corresponding to the year 2007 were distributed in June and transfers corresponding to 2008 were distributed in two parts. The first part was distributed in July and the second one in September. The mining canon corresponding to the year 2008 was redistributed in one transfer in July 2009. The one corresponding to the year 2009 was also redistributed in one transfer in July 2010.

Finally, figure 2.9 shows how municipalities spent income from the mining canon in 2008. Spending is diversified across economic sectors, including special categories for health and drainage as well as administration and planning. Revenues from mining-based transfers totaled over one billion USD only for the year 2008.

2.3 Data

I use a dataset self-reported by municipalities (RENAMU). This dataset has yearly data from 2002 to 2010 on income, spending and numerous municipality-level indicators of development and investments. For the universe of municipalities[15] in Peru, I merge municipal-level data on municipality income with detailed environmental investment indicators for the 2005 - 2010 time period. I use variation in mineral prices to analyze the effect of municipality income on environmental investments, where income is the real net municipality income, i.e. the deflated[16] total municipality income minus debts and minus the balance from the previous year. The RENAMU dataset is publicly available through the National Statistics Bureau (INEI) website. The municipality sample size is around 1800 observations per year.

[15]Twelve municipalities out of 1834 were dropped due to border changes during the 2001-2010 period.
[16]Municipality income is deflated with a Consumer Price Index (CPI) that varies by state and year.

I also use mining transfer data publicly available through the Ministry of Economics and Finance's website (MEF). I construct a panel of all the mining canon transfers made by the central government to the local governments for the universe of municipalities in Peru from 2002 to 2010. I further include data on state mineral "production" and international mineral prices.

Table 2.1 gives summary statistics on municipality income and, transfers, as well as a price index for zero, one, two and three year lags. Table 2.2 gives summary statistics on environmental investment outcomes.

Not all municipalities report data in the RENAMU dataset. Table 2.3 shows the number of municipalities that report income data per year. Income data is not available for all municipalities in any year[17] but the number of municipalities that report data has increased over time.

2.4 Identification Strategy

The identification strategy relies on using exogenous variation in mineral prices to estimate the impact of an increase of municipality income on environmental investment outcomes. Specifically, I estimate:

$$y_{jt} = \alpha + \beta Income_{j,t-n} + \eta_j + \delta_t + \varepsilon_{jt} \tag{2.3}$$

where y_{jt} is some environmental investment outcome for municipality j in year t, $Income_{j,t-n}$ denotes the log of the real net income of municipality j in year t, $t-1$, $t-2$ or $t-3$ depending on the lag assumed, η_j is a municipality fixed effect, δ_t is a time (year) fixed effect and ϵ_{jt} is an error term. Standard errors are clustered at the state level due to the distribution scheme used by the Peruvian government to allocate mineral transfers. I use different lags between the year of the income and the year of the outcome in order to create flexibility in the identification of the effect. In other words, I allow the municipality up to three years to undertake the environmental investment.

A key issue in the identification strategy is that municipality income is endogenous. First, because mining transfers are a component of a municipality's total income and are distributed based on the UBN indicator, poorer municipalities receive more transfers. However, this type of endogeneity is partially taken care of by a municipality fixed effect. The main source of endogeneity comes from other factors linked to environmental investments that also affect income and transfers. One example of such factors is strikes. Individuals in very polluted municipalities or municipalities that have low levels of environmental investments might undertake more strikes, which can reduce mining profits, transfers and municipality income.

Therefore, I use a price index as an instrumental variable. The price index is a linear combination of the price of eight[18] minerals (gold, silver, tin, lead, copper, zinc, iron and

[17] This paper studies 1834-12=1822 municipalities.

[18] These minerals represented almost 100% of Peruvian mining exports in 2008.

molybdenum) where the weights are the share of a state's production per mineral (with respect to national production) in a pre-period year (2001). I look at relative changes in mineral prices because minerals are measured in different units. Thus, prices are divided by the price of the mineral in a base year (1998). Specifically, the instrument used is the following:

$$P_{st} = \sum_{m=1}^{M=8} \frac{q_{ms}}{Q_m} * \frac{P_{mt}}{P_{m,t=0}} \tag{2.4}$$

where P_{st} is a price index that varies by state and year, $\frac{q_{ms}}{Q_m}$ are the weights for state s and mineral m and $\frac{P_{mt}}{P_{m,t=0}}$ is the relative change in price of mineral m. The price index can also be seen as a measure of a state's potential mining wealth.

Using exogenous variation in mineral prices, the channel used in the identification is the following: an increase in mineral prices increases the mining canon which itself increases municipality income. The instrument is correlated with income and mining transfers as shown in figures 2.5 and 2.6 since transfers depend on the profits of mining firms and these depend on mineral prices. Further, the instrument should be uncorrelated with the error term because mineral prices are determined in international markets and are thus exogenous to Peruvian municipalities' level of environmental investments. This assumption is tested later by excluding producing municipalities.

Table 2.4 shows the specific income and price years used for zero, one, two and three year lags. Following the timing of the mining canon distribution described in figure 2.8, I use the average of two years' prices until 2007[19] as an instrumental variable for municipality income. From 2008 onward, only the price of the previous year is used.

2.5 Effect of Municipality Income on Environmental Investments

2.5.1 Testing for Crowding out of Funds

Before trying to estimate the effect of municipality income on environmental investments, we must show that:

1. The price index increases the mining canon and municipality income

[19] Note that in Figure 2.8 (a), the prices in year 1 explain the transfers for only half of year 2 (from July to December) and that the first part of the transfer for year 2 is based on prices in year 0. For example, suppose year 0 is 2001, year 1 is 2002, year 2 is 2003 and year 3 is 2004. To know what prices determined the canon received by municipalities in 2003, one can take the average of the prices of 2001 and 2002 because the prices in 2001 explain the canon from January to June 2003 and the prices in 2002 explain the canon from July to December 2003.

2. The mining canon increases municipality income. In particular, we need to rule out a full crowding out effect of the canon on other transfers. That is, we need to show that the central government is not diverting funds from canon rich-municipalities because it considers that they have enough funding of their own.

To show this, I use the RENAMU dataset and collect data on all the municipalities' yearly income from 2005 to 2010. There are two measures of income available. The first one is the anticipated income of the municipality ("Presupuesto Inicial de Apertura", PIA) which is the income a municipality expects to collect based on projections by the central government. The second one is the actual received or "executed" income ("Ingreso Ejecutado"). To test a possible crowding out of funds, I use municipalities' executed income.

There are three main issues in the RENAMU dataset. First, as shown in table 2.3, not all municipalities report data. This is particularly true for the initial years of the RENAMU survey, where, on average, around 5% of the municipalities do not report data. This creates a selection issue because poorer municipalities are the ones most likely not to report. Thus, our sample is biased towards the richer municipalities. The implication in terms of the interpretation of the results is that they may be an upper bound of municipalities' environmental investments. Second, the data for the studied environmental investments are not available for every year in the 2005-2010 period. Thus, the results do not show a continuous yearly analysis. Table 2.5 shows the list of environmental investments tested and the years for which each outcome was available. Third, the data are self-reported by municipalities.

Keeping these issues in mind, I test the effect of the price index and the mining canon on municipality income. First, I estimate the first stage, the effect of the price index on municipality income. Column (1) in table 2.6 shows that a one unit increase in the price index increases the real net income of a municipality by 2,622,689 soles[20] in the same year (i.e. with a zero year lag). Column (2) shows that the price index also increases the real canon. In particular, a unit increase in the price index increases the real canon by 1,557,119 soles. Column (3) shows that the real canon increases municipalities' real net income at a 1 by 1 level, i.e. that a one sol increase in the mining canon increases municipalities' real net income by approximately one sol. Thus, there is no evidence of crowding out on average. Column (4) shows the Two-Stage-Least-Squares (2SLS) estimation of municipalities' real net income on the real mining canon where the real mining canon is instrumented with the price index. The results show that the mining canon increases municipalities' income when mineral prices are used as an instrument, although this time the coefficient is larger than one.

Columns (1), (2) and (3) show OLS estimations, while column (4) shows a 2SLS estimation. All results are significant at the 1% level.

[20]On average, during the 2005-2010 time period, the exchange rate was roughly 3 soles for 1 USD.

2.5.2 Effect of the Real Net Municipality Income on Environmental Investments

I analyze six groups of environmental investments: green spaces, environmental offices, water, waste, environmental management and activities undertaken to preserve the environment. All regressions include municipality and year fixed effects. Standard errors are clustered at the state level. Only 2SLS results are shown. Regressions do not include the entire 2005-2010 time period because no outcome had data for all years. Thus, outcomes are for particular years within the 2005-2010 time period and the years used for each outcome are shown in each table. Only significant outcomes (for all lags) are reported in this section.

I begin by estimating the first stage and regress the log of the real net municipality income on the price index for zero, one, two and three year lags. Table 2.7 shows that the first stage is significant at the 1% level for all lags. In particular, a one unit increase in the price index increases the real net municipality income by around 26%.

Tables 2.8 and 2.9 show the results of 2SLS regressions that test the effect of municipality income on green areas investments. Columns (1) through (4) in table 2.8 show that a one percent increase in the real net municipality income increases green areas in squares by around 39 square meters after a two year lag and by 122 square meters after a three year lag. These results are significant at the 10% and 5% level respectively. Column (2) in table 2.9 shows that after a three year lag, a one percent increase in the real net municipality income increases green areas in parks by around 63 square meters and column (6) that it increases green areas in berms by around 44 square meters after a three year lag. On average, the results from tables 2.8 and 2.9 show that an increase in municipality income leads to more investments in green areas but the results are not significant for all lags.

Table 2.10 analyzes water treatment investments. Columns (2), (3) and (4) in table 2.10 show that a one percent increase in the real net municipality income increases the probability that the municipality uses an activated sludge treatment[21] by 0.000108 after a one year lag, by 0.00015 after a two year lag and by 0.000132 after a three year lag. These results are all significant at the 10% level. Similarly, columns (6), (7) and (8) in table 2.10 show that a one percent increase in the real net municipality income increases the probability that the municipality uses a septic tank treatment[22] by 0.000831 after a one year lag (significant at the 5% level), by 0.000799 after a two year lag and by 0.000837 after a three year lag (significant at the 1% level).

Table 2.11 studies the effect of municipality income on the probability of having a local environmental action plan and a municipal waste plan. Column (1) shows that increasing

[21]An activated sludge treatment is a process for treating sewage and industrial waste waters using air and a biological floc composed of bacteria and protozoans.

[22]A septic tank is a small-scale sewage treatment system common in areas with no connection to main sewage pipes. A septic tank generally consists of a 4000 to 7500 liter tank (or sometimes more than one tank) connected to an inlet waste water pipe at one end and a septic drain field at the other.

municipality income by one percent leads to a 0.00056 decrease in the probability that the municipality has a local environmental action plan. Columns (2), (3) and (4) also show a very small negative effect but it is no longer significant after a one, two or three year lag. Columns (5) through (8) in table 2.11 show an overall positive effect of municipality income on the probability of having a municipal waste plan. However, only column (8) shows a significant effect at the 5% level, a 0.000664 increase in the probability of having a municipal waste plan after a three year lag. Table 2.11 suggests that an increase in local income does not lead to more general environmental plans but can lead to specific (targeted) plans for particular investments.

Table 2.12 shows the effect of municipality income on "low" amounts of daily waste (1,000 to 2,999 kg and 3,000 to 9,999 kg) collected by the municipality. Column (4) shows that a one percent increase in the real net municipality income increases the probability that a municipality collects 1,000 to 2,999 kg of daily waste by 0.000321 after a three year lag. This result is significant at the 10% level. Column (6) shows that a one percent increase in the real net municipality income decreases the probability that a municipality collects 3,000 to 9,999 kg of waste by 0.000554 after a one year lag (significant at the 5% level) and column (7) that it does so by 0.000606 after a two year lag (significant at the 1% level). Although the magnitude of the effects is very small, these results suggest that municipalities have a higher probability of collecting smaller amounts of waste and a lower probability of collecting higher amounts of waste. A possible explanation is that waste is being collected more often and thus smaller quantities are being picked up daily.

Table 2.13 is similar to table 2.12 but higher quantities of collected waste are studied (50,000 to 99,999 kg and 100,000 kg or more). Columns (3) and (4) show that a one percent increase in the real net municipality income decreases the probability that a municipality collects 50,000 to 99,999 kg of waste by 0.000157 after a two year lag and by 0.000165 after a three year lag. Column (7) in table 2.13 shows that for high amounts of daily waste collection (100,000 kg or more), a one percent increase in the real net municipality income increases the probability that municipalities collect these amounts of waste by 0.000109. This result is significant at the 10% level after a two year lag. These results are very small in magnitude and, as seen in the summary statistics, concern a very small share (2%) of the (probably richer) municipalities.

Table 2.14 studies the effect of municipality income on the frequency of waste collection. Column (1) shows that a one percent increase in the real net municipality income increases the probability that a municipality collects waste every other day by 0.000735 after a zero year lag (significant at the 10% level). The effect seems to continue after a one, two and three year lag but the results are no longer significant. Columns (5) through (8) study the effect of municipality income on weekly waste collection and show that a one percent increase in the real net municipality income decreases the probability that a municipality collects waste weekly by 0.000941 after one year lag, by 0.000731 after a two year lag and by 0.000856 after a three year lag. These results are significant at the 10%, 5% and 10% level respectively and suggest that, on average, municipalities are collecting waste more often.

Finally, table 2.15 tests the effect of an increase in municipality income on the destination of the collected waste. Column (1) shows that after a zero year lag, a one percent increase in the real net municipality income increases the percent of waste disposed in an open dump by 0.12%. This results is significant at the 10% level. Municipalities declare the percent of waste that is recycled, burned, or disposed of (in a landfill, open dump, river, lake or sea). Therefore, the increase in the percent of waste disposed in an open dump should be interpreted with respect to these other options. Column (2) shows a lower positive effect after a one year lag while columns (3) and (4) show a negative effect after a two and three year lag, suggesting that other options might substitute for open dumps after some years. However, none of these results are significant.

Results should be interpreted in light of the period, data and identification strategy used as a few caveats are in place. First, testing is limited to measurable and reported outcomes. Second, although many of the tested outcomes are relatively fast-reacting outcomes, some investments may require further time lags to be undertaken and reported. Third, municipal governments may be constrained by the availability of funds or by administrative divisions of responsibilities between the central and local governments.

2.5.3 Effect of the Real Net Municipality Income on Environmental Investments by Income Level

In order to assess possible heterogeneous effects of income levels on environmental investments, I divide municipalities into income categories and estimate again the significant environmental investments. The categories are based on municipalities' net real income in the year 2008 because this was the year when the greatest number of municipalities reported income. I divide income categories into quartiles, where the first quartile includes municipalities that had a net real income of less than 792,209 soles, the second quartile includes municipalities that had a net real income between 792,209 soles and 1,796,465 soles, the third quartile includes municipalities that had a net real income between 1,796,466 soles and 4,398,982 soles, and the fourth quartile includes municipalities that had a net real income equal to 4,398,983 soles or more. I find that most of the effects were driven by municipalities in the second, third and fourth quartiles (results are not shown). Specifically, the results for green spaces were entirely driven by municipalities in the fourth quartile; the results for water treatments were driven by the second, third and fourth quartiles; and the results for the amount of waste collected and the frequency of waste collection were driven by the third and fourth quartiles. The results for the destination of the collected waste seem to be driven by the second quartile.

2.6 Testing of Non-Environmental Outcomes and Test of the Exclusion Restriction

2.6.1 Testing of Non-Environmental Outcomes

After showing that an increase in municipality income translates into some additional environmental investments, I test whether there are any effects of an increase in municipality income on other non-environmental investments. I use the RENAMU dataset for the available years 2005, 2007, 2008 and 2009 and collect data on numerous municipality level indicators of development and investment. In particular, I estimate the impact of municipality income on outcomes such as road construction and maintenance, the amount of health, education and sports related infrastructure built, and the number of small companies registered.[23] Tables 2.16 and 2.17 show the results. Columns (1), (2), (3) and (4) in table 2.16 show positive and significant effects for the number of months that health investments take to be completed following a zero, one , two and three year lag. In particular, a one percent increase in the real net municipality income increases the number of months that health investments take by 0.01732/ 100 of a month (0.005 days) after a 0 year lag, by 0.00921/100 of a month (0.002 days) after a 1 year lag, by 0.01417/100 of a month (0.004 days) after a 2 year lag and by 0.01723/100 of a month (0.005 days) after a 3 year lag. These results could reflect the fact that bigger health investments are taking place (and therefore take a longer time to complete) or that municipalities require more time to complete additional investments. I do not find any significant effect on the number of hospitals, health centers, health posts or pharmacies (regressions are not shown). Column (5) shows that a one percent increase in the real net municipality income leads to a 845 soles decrease in the cost of repairing roads after a two year lag (significant at the 10% level). I find no effect of municipality income on the number of square meters of repaired roads (regression not shown). Column (6) finds that a one percent increase in the real net municipality income increases the cost of road constructions by 4,362 soles after a three year lag. I also find no effect of municipality income on the number of kilometers of constructed roads (regression not shown).

Table 2.17 analyzes the effect of an increase in municipality income on other non-environmental investments. The total number of observations in this table is significantly higher than the previous tables because several investments per municipality are aggregated together. Columns (1) and (2) show that a one percent increase in the real net municipality income leads to a 4,238 soles increase in the total cost of public (municipality) investments after a two year lag and to a 5,760 soles increase after a three year lag. These results are significant at the 10% and 5% level respectively. Columns (3) and (4)

[23] The outcomes studied are: cost and time of investments in five categories (education, health, transportation, electricity and water treatment, and tourism), the cost and length of constructed and repaired roads, rural roads and sidewalks, different indicators of sports infrastructure, different indicators of health infrastructure (such as hospitals, health centers, health posts and pharmacies) and the number of small businesses registered.

show that a one percent increase in the real net municipality income leads to a 1,442 soles increase in the total cost of investments related to education after a 2 year lag (significant at the 10% level) and to a 2,644 soles increase after a three year lag (significant at the 5% level). Finally, columns (5) and (6) display the results of a one percent increase in the real net municipality income on the total cost of investments in transportation and communications. After a two year lag, a one percent increase in the real net municipality income increases the total cost of investments in transportation and communications by 9,378 soles, and after a 3 year lag it does so by 9,676 soles (both results are significant at the 10% level). The results in this section suggest that municipalities spent their income on health investments, on the construction and maintenance of roads, on educational investments and in transportation and communications investments. However, the mechanisms that could explain why certain investments take longer to complete or have a higher cost cannot be identified with the information available in the RENAMU datasets.

2.6.2 Trade-Offs Between Environmental and Non-Environmental Investments

When municipalities receive additional revenues, they have to decide whether to invest in either environmental investments or other, non-environmental, investments. To capture this trade-off, we would like to estimate an elasticity between environmental and non-environmental investments. However, the RENAMU dataset does not allow the estimation of this elasticity. In particular, many of the reported environmental investments are not measured in monetary values; they are mainly indicator variables as to whether an investment took place. On the other hand, the non-environmental investments are measured either in monetary terms or in the amount of time (in months) a particular investment took to complete. Thus, with this data, I am not able to construct an indicator that captures these trade-offs.[24] Figure 2.2 shows that the programs that receive the most spending are administrative, land transportation and sanitation programs, but we cannot estimate marginal effects.

2.6.3 Test of the Exclusion Restriction

Using the price index as an instrumental variable for endogenous municipality income relied on the assumption that mineral prices were not affecting the error term of the estimated regressions. To test the validity of this assumption, I again estimate the significant environmental investments, using the same specifications but excluding all

[24] In order to know whether the results are the "expected" results, one would have to have a measure of municipalities' environmental preferences. If municipalities have high levels of environmental preferences, we can expected a relatively high share of environmental investments per one sol of investments. On the other hand, if municipalities have low levels of environmental preferences, we can expect a relatively low share of environmental investments per one sol of investments.

mineral-producing municipalities. In total, I drop 66 producer municipalities.[25] By excluding producer municipalities, we are now looking at municipalities (in the same state as a producer municipality) that are not producers themselves. Thus, we would expect no effect of mineral extraction itself on environmental investments. As shown in tables 2.18, 2.19 and 2.20, 19 out of the 23 tested environmental investments are significant and similar in magnitude to when the producer municipalities are included.[26] The point estimates are not statistically different from the results that include producer municipalities. This suggests that it is valid to assume that the exclusion restriction holds for this instrumental variable.

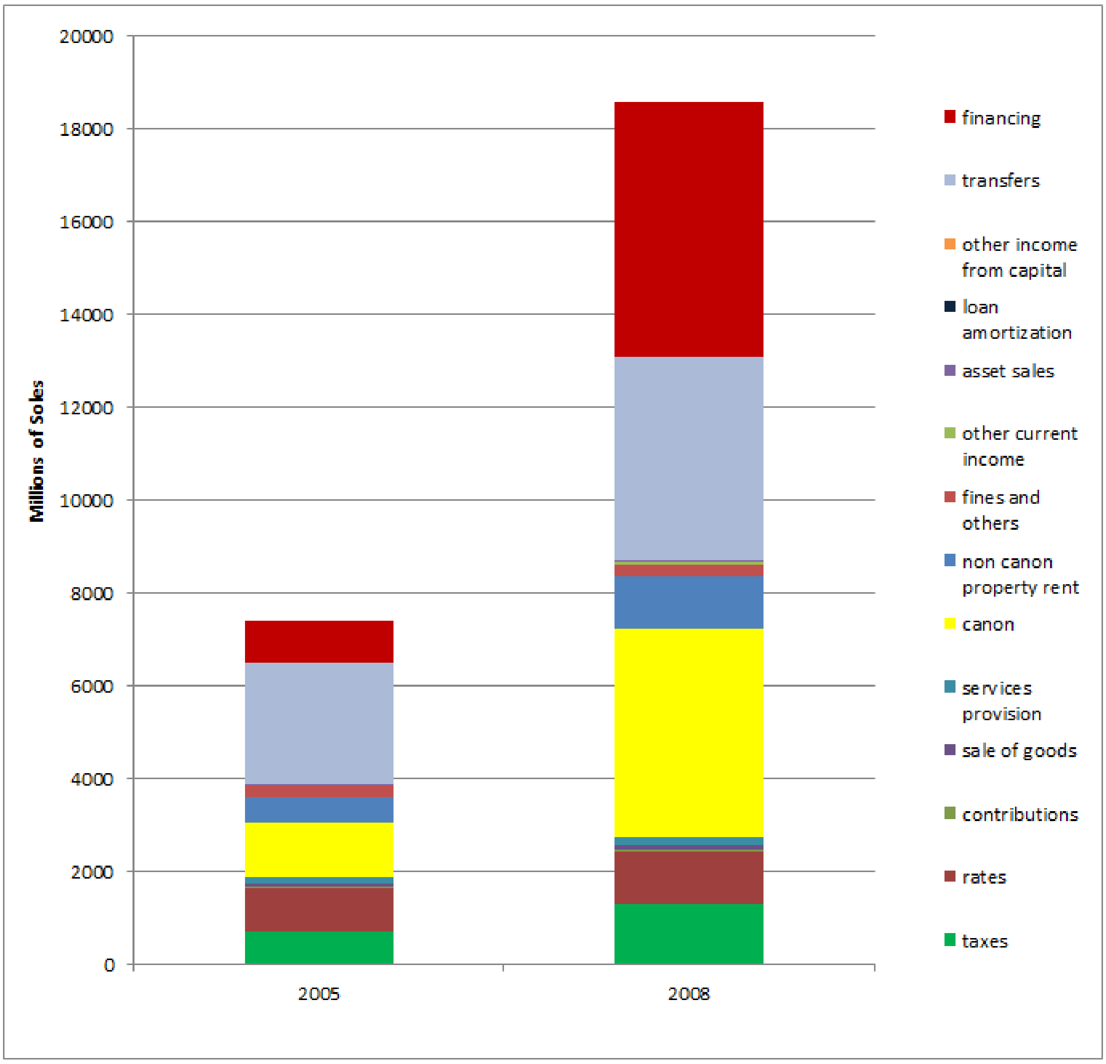
2.7 Conclusion

This paper studies whether municipalities in Peru undertake more environmental investments when their income increases. I test whether municipalities invest more in green spaces, water treatment, environmental management, waste collection and programs that incentivize environmental protection. I show that mineral prices increase mining transfers and municipality income. Using variation in international mineral prices as an instrumental variable for municipality income, I find evidence of significant effects of an increase in municipality income on some environmental investments. In particular, municipalities invest more on green spaces (squares, parks and berms), water treatment (activated sludge and septic tank treatments), and municipal waste plans. Municipalities also invest more in the frequency of waste collection (every other day versus weekly) and this seems to be reflected in smaller amounts of daily collected waste. In the very short run, an increase in municipality income also leads to a lower probability of having a local environmental action plan and to a higher probability of disposing of the collected waste in open dumps (instead of recycling or disposing of waste in a landfill, for example). I also test whether municipalities invest more in non-environmental investments when their income increases and find evidence of additional investments in education, health and transportation. The magnitude of the effect on environmental investments is small given the large increase in municipality income and suggests that there may be room for additional environmental policies such as minimum standards, tax incentives or environmental campaigns.

[25] These are pre-period (2001) producer municipalities.

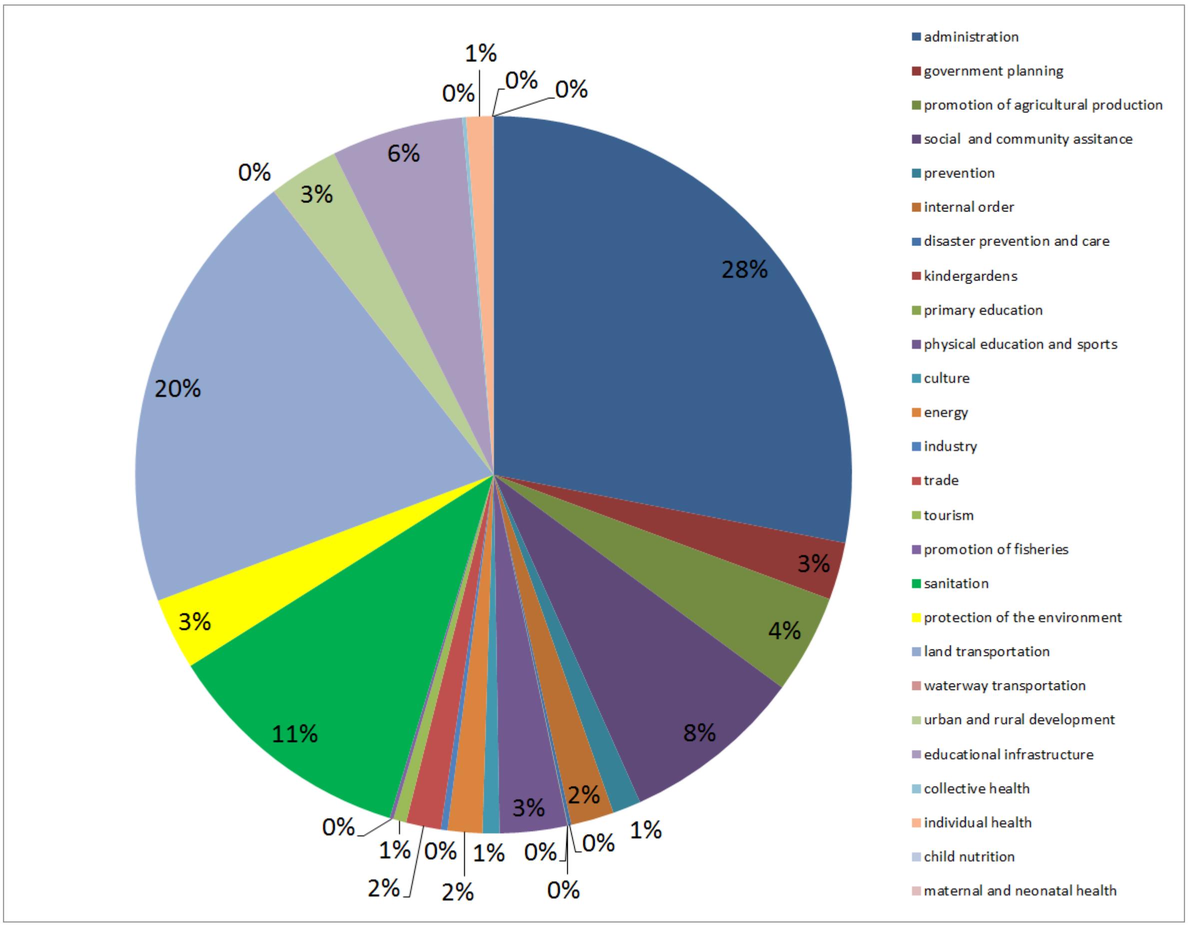
[26] The four outcomes that become insignificant when the producer municipalities are dropped are: the activated sludge treatment for a 3 year lag (p-value=0.101), the municipality collects 1,000 to 2,999 kg of daily waste for a 3 year lag (p-value=0.18), the municipality collects 100,000 kg or more of daily waste for a 2 year lag (p-value=0.225) and the municipality collects waste every other day for a 0 year lag (p-value=0.12).

Figure 2.1: Municipality Income by Source of Revenue (2005 and 2008)



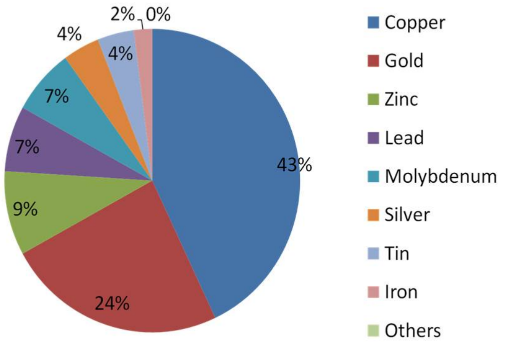
Source: Elaborated with RENAMU data.

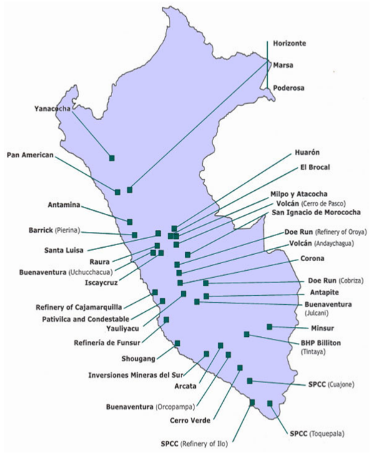
Figure 2.2: Municipality Spending by Major Programs (2008)



Source: Elaborated with MEF data.

Figure 2.3: Exports by Minerals in Millions of USD for the Year 2008 (a), Main Mining Units, (b)

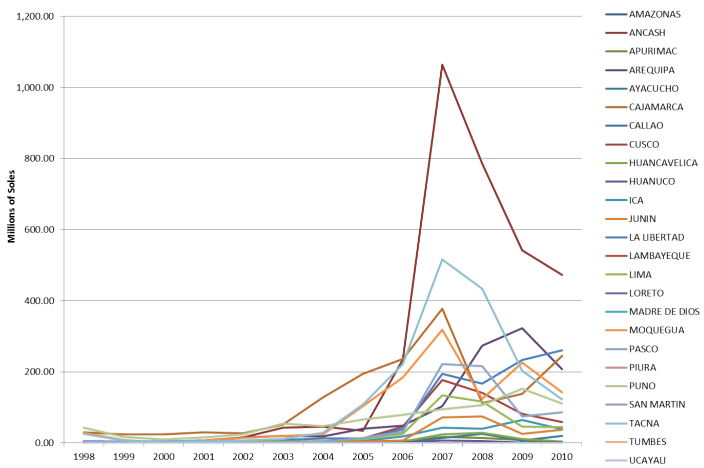


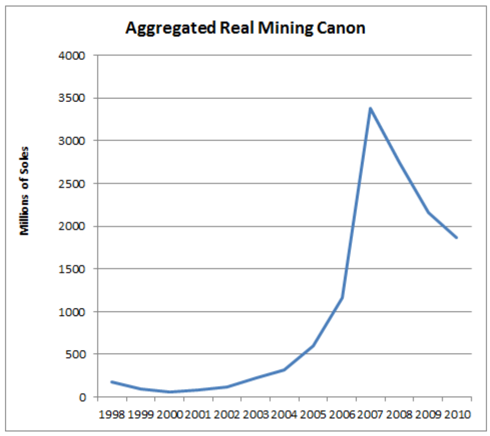


source: MINEM

source: MINEM

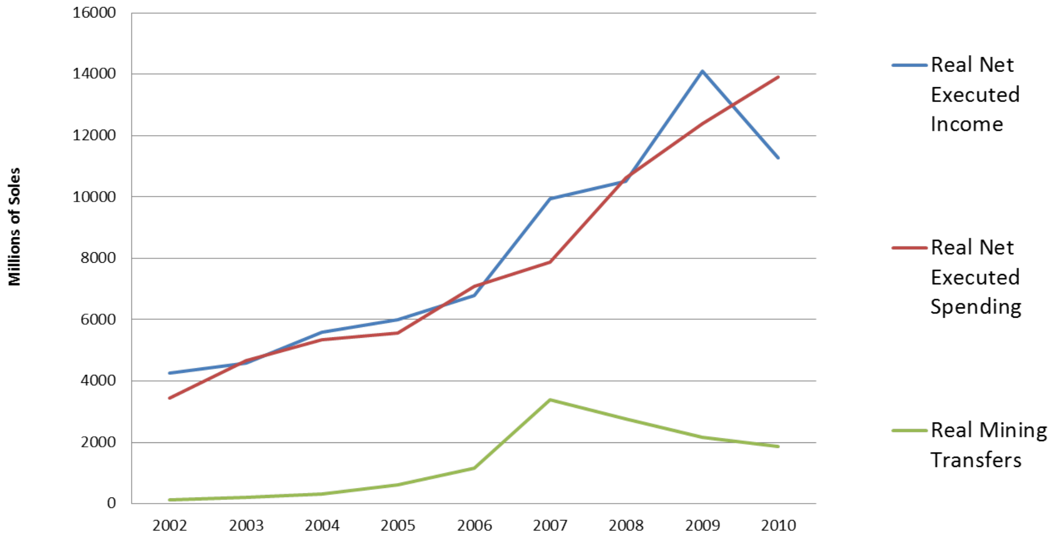
Figure 2.4: Real Mining Canon Variation by State (a) and Aggregated Real Mining Canon (b) (1998-2010)





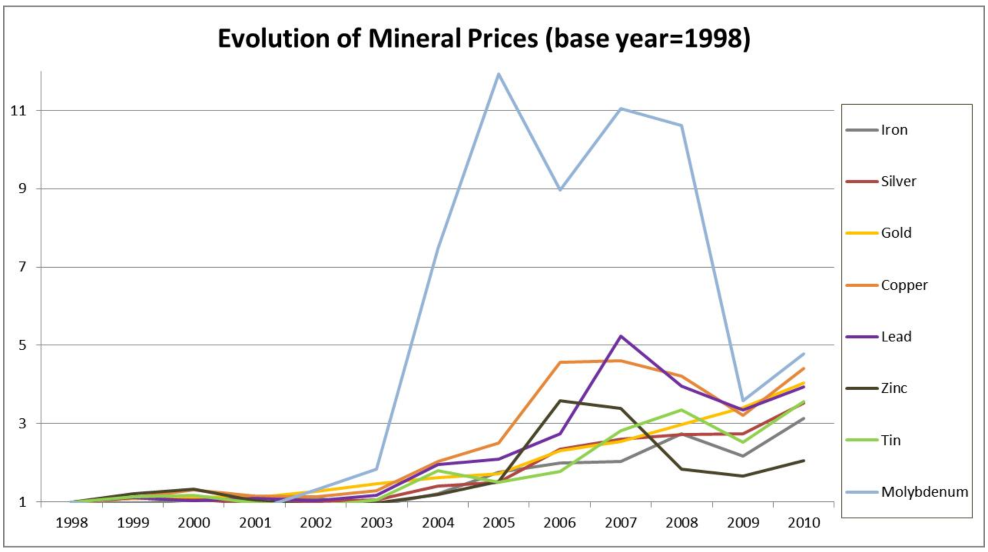
Source: Elaborated with MEF data.

Figure 2.5: Evolution of the Aggregated Real Net Municipality Income, Municipality Spending and the Real Mining Canon



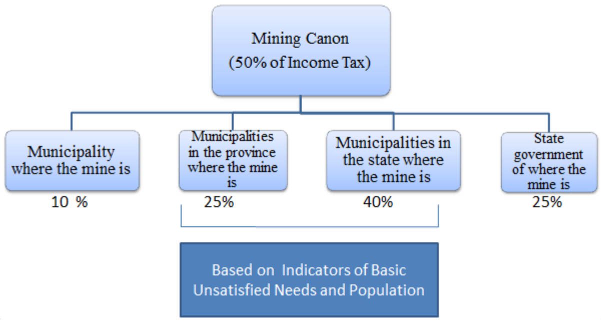
Source: Elaborated with RENAMU data.

Figure 2.6: Evolution of the Prices of the Main Minerals Exported by Peru (1998-2010)



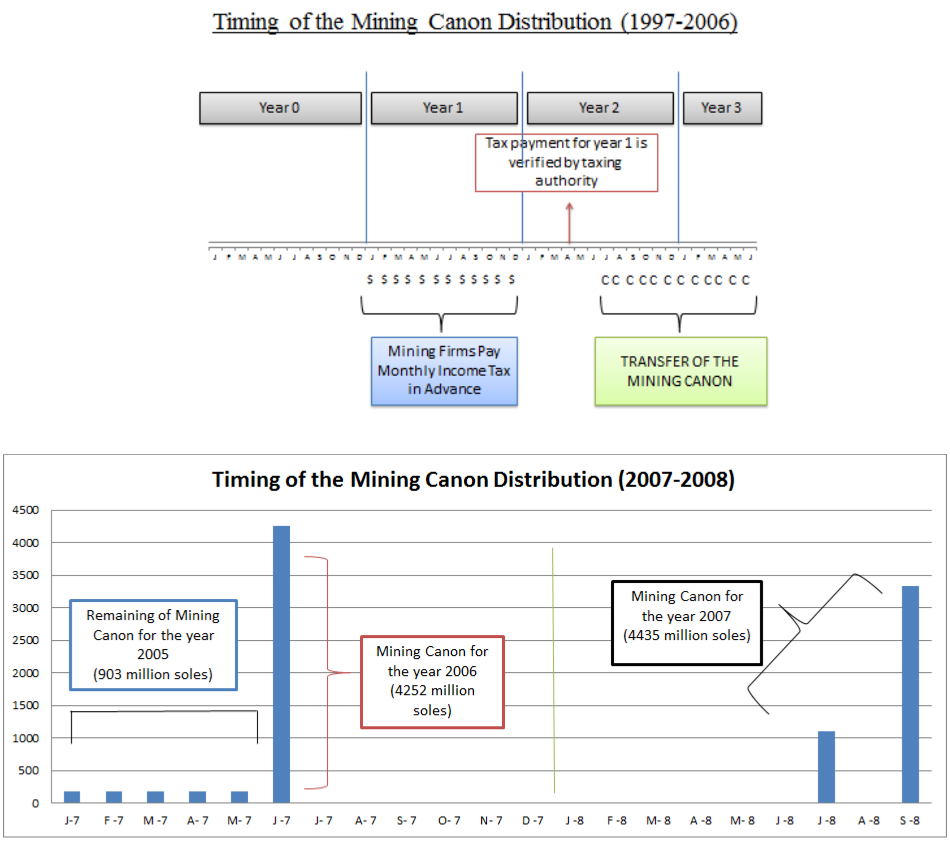
Source: Elaborated with MINEM data.

Figure 2.7: Mining Canon Distribution to Local Governments



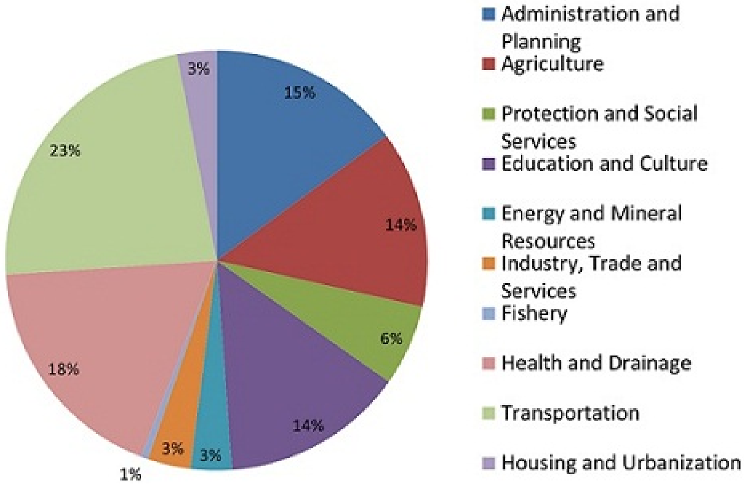
Source: Adapted from MINEM.

Figure 2.8: Timing of the Mining Canon Distribution for 1997-2006 (a) and 2007-2008 (b)



Source: Top panel (a): Adpated from CAD (2008), Bottom panel (b): Adapted from SNMPE (2008).

Figure 2.9: Municipality Spending of the Mining Canon Budget by Sector, 2008



Source: MEF

Table 2.1: Summary Statistics on Municipality Income, Mineral Transfers and the Price Index

Variable	Obs	Mean	Std. Dev	Min	Max
year	6	2007.5	1.707903	2005	2010
municipality code	1822	106506.8	67096.12	10101	250401
state code	25	10.59605	6.71786	1	25
real municipality income (soles)	10541	5560447	24000000	0	1280000000
real lagged 1 year municipality income (soles)	10444	5067381	22500000	0	1280000000
real lagged 2 year municipality income (soles)	10360	4189338	18000000	0	785000000
real lagged 3 year municipality income (soles)	10307	3604776	16500000	0	785000000
log (real municipality income)	10541	14.47122	1.248605	0	20.97306
log(real lagged 1 year municipality income)	10444	14.33314	1.378859	0	20.97306
log (real lagged 2 year municipality income)	10359	14.16841	1.345424	0	20.48081
log (real lagged 3 year municipality income)	10306	13.99337	1.325377	0	20.48081
real canon	10932	1061252	4861791	0	184000000
real lagged 1 year canon	10932	887665.2	4415104	0	168000000
real lagged 2 year canon	10932	697816.4	3976018	0	167000000
real lagged 3 year canon	10932	467633.8	3221242	0	167000000
price index	10932	1.018819	1.197475	0	6.103972
price index 1 year lag	10932	0.9384865	1.173542	0	6.103972
price index 2 year lag	10932	0.8002685	1.066071	0	6.103972
price index 3 year lag	10932	0.7598636	1.009196	0	6.482427

Table 2.2: Summary Statistics for Significant Environmental Investments

Variable	Obs	Mean	Std. Dev	Min	Max
green areas squares (sq.m)	7095	3968.164	23107.74	0	1299197
green areas parks (sq.m)	7095	11927.35	70583.97	0	1450449
green areas berms (sq.m)	7095	4872.003	37877.22	0	970000
activated sludge treatment	9110	0.003512	0.0591665	0	1
septic tank treatment	9110	0.102963	0.303928	0	1
local environmental action plan	8904	0.1323001	0.3388358	0	1
municipal waste plan	7752	0.1652477	0.3714279	0	1
municipality picks up daily 1000 to 2999 kg of waste	9074	0.1643156	0.3705822	0	1
municipality picks up daily 3000 to 9999 kg of waste	9074	0.110205	0.3131623	0	1
municipality picks up daily 50000 to 99999 kg of waste	9074	0.0202777	0.1409564	0	1
municipality picks up daily 100000 kg or more of waste	9074	0.0224818	0.1482525	0	1
municipality picks up waste every other day	8660	0.1327945	0.3393721	0	1
municipality picks up waste weekly	8660	0.2193995	0.4138637	0	1
pct of waste that ends up in an open dump	7865	60.22657	44.31601	0	100

Table 2.3: Number of Municipalities that Reported Income Data to RENAMU per Year

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
Municipalities that Reported Income Data	1762	1722	1714	1729	1730	1750	1815	1806	1811

Table 2.4: Concordance between Variables with Respect to Lags

	0 years lag		1 year lag		2 years lag		3 years lag	
Outcome	Income	Price	Income	Price	Income	Price	Income	Price
2004	2004	avg.2002-2003	2003	avg.2001-2002	2002	avg.2000- 2001	2001	avg.1999-2000
2005	2005	avg. 2003-2004	2004	avg.2002-2003	2003	avg.2001-2002	2002	avg.2000-2001
2006	2006	avg. 2004-2005	2005	avg.2003-2004	2004	avg.2002-2003	2003	avg.2001-2002
2007	2007	avg. 2005-2006	2006	avg.2004-2005	2005	avg.2003-2004	2004	avg.2002-2003
2008	2008	2007	2007	avg.2005-2006	2006	avg.2004-2005	2005	avg.2003-2004
2009	2009	2008	2008	2007	2007	avg.2005-2006	2006	avg.2004-2005
2010	2010	2009	2009	2008	2008	2007	2007	avg.2005-2006

Table 2.5: List of Tested Environmental Investment

*	#	OUTCOMES	TIME PERIOD
GREEN SPACES OUTCOMES			
No	1	municipality preserves green areas (yes/ no)	2005 & 2007-2009
Yes	2	if yes to 1), what is the area (in square meters) of the green areas	2005 & 2007-2009
ENVIRONMENTAL OFFICE OUTCOME			
No	3	municipality has an environmental office (yes/ no)	2005 & 2008-2010
WATER OUTCOMES			
No	4	used (dirty) waters receive treatments (yes/ no)	2006-2010
Yes	5	if yes to 4), then what type of treatments are used	2006-2010
ENVIRONMENTAL MANAGEMENT OUTCOMES			
Yes	6	municipality has a waste management plan (yes/no)	2006-2010
Yes	7	if yes to 6), what type of plan does it have	2006-2010
Yes	8	municipality has tools of environmental management (yes/no)	2006-2010
Yes	9	if yes to 8), what type of tools does it have	2006-2010
WASTE OUTCOMES			
No	10	municipality picks up waste (yes/no)	2006-2010
Yes	11	if yes to 10), what is the average daily waste collection	2006-2010
Yes	12	frequency of waste collection	2006-2010
Yes	13	what is the final destination of the collected waste	2006-2010
ACTIVITIES UNDERTAKEN TO PRESERVE THE ENVIRONMENT			
No	14	municipality undertook activities to preserve the environment (yes/ no)	2006-2009
No	15	if yes to 14), what activities did the municipality undertake	2006-2009

Notes: "*" means significant. For outcome 2, the green areas are squares, parks, gardens and ovals, and berms. For outcome 5, the types of water treatments are facultative ponds, aerated lagoons, anaerobic treatment lagoons, activated sludges, septic tanks, Imhoff tanks, biological filters and other. For outcome 7, the possible plans are an integrated solid waste management plan, a municipal solid waste management plan, a solid waste collection system, a solid waste transformation program and other. For outcome 9, the possible environmental management tools are a local environmental diagnosis, a local environmental action plan, a local environmental agenda, a local environmental policy, a local system of environmental management, environmental evaluations, environmental audits and other. For outcome 11, the average daily waste collection brackets are less than 1,000 kg, 1,000 - 2,999 kg, 3,000 - 9,999 kg, 10,000 - 49,999 kg, 50,000 - 99,999 kg and more than 100,000 kg. For outcome 12, the possible frequencies of waste collection are daily, every other day or weekly. For outcome 13, the reported possible final destinations are landfills, open dumps, rivers or lakes or the sea, burned, recycled and other. For outcome 15, declared activities to preserve the environment were environmental awareness campaigns, contests on environmental initiatives, environmental projects support, institutional arrangements, educational talks and taking care of environmental complaints made by the population.

Table 2.6: The Price Index and the Mining Canon Increase Municipalities' Executed Income

	(1) OLS, first stage income	(2) OLS canon	(3) OLS income	(4) 2SLS income
price index	2622689***	1557119***		
	(507873)	(325970)		
canon			1.030***	1.668***
			(0.111)	(0.234)
Obs	10541	10932	10541	10540
muni. f.e.	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Income is the real net municipality income and canon is the real municipal canon. Standard errors clustered at the state level. All outcomes are for the years 2005 - 2010.

Table 2.7: Municipality Level First Stage Results, OLS

	(1) log income	(2) log income	(3) log income	(4) log income
price index at t	0.265***	0.270***	0.261***	0.244***
	(0.0851)	(0.0606)	(0.0442)	(0.0364)
Obs	10541	10444	10359	10306
lag	0 year	1 year	2 year	3 year
muni. f.e.	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Income is the real net municipality income. All regressions include municipality and year fixed effects. Standard errors clustered at the state level. All outcomes are for the years 2005 - 2010.

Table 2.8: Green Spaces Outcomes (1), 2SLS

	(1) squares	(2) squares	(3) squares	(4) squares	(5) parks	(6) parks
log income	3883 (3281)	3704 (3107)	3933* (2120)	12221** (5352)	4195 (5071)	2319 (2699)
Obs	6830	6735	6651	6743	6830	6735
lag	0 year	1 year	2 year	3 year	0 year	1 year
muni. f.e.	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Income is the real net municipality income. All regressions include municipality and year fixed effects. Standard errors clustered at the state level. All outcomes are for the years 2005 and 2007-2009. Squares and parks are measured in square meters. Mean of variable "squares" in 2005: 3,438 m2. Mean of variable "parks" in 2005: 10,577 m2.

Table 2.9: Green Spaces Outcomes (2), 2SLS

	(1) parks	(2) parks	(3) berms	(4) berms	(5) berms	(6) berms
log income	89 (1409)	6324* (3549)	8098 (6858)	3418 (2252)	2117 (1616)	4456** (2065)
Obs	6651	6743	6830	6735	6651	6743
lag	2 year	3 year	0 year	1 year	2 year	3 year
muni. f.e.	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Income is the real net municipality income. Standard errors clustered at the state level. All outcomes are for the years 2005 and 2007-2009. Parks and berms are measured in square meters. Mean of variable "parks" in 2005: 10,577 m2. Mean of variable "berms" in 2005: 3,690 m2.

Table 2.10: Water Treatment Investments, 2SLS

	(1) activated sludge treatment	(2) activated sludge treatment	(3) activated sludge treatment	(4) activated sludge treatment	(5) septic tank treatment	(6) septic tank treatment	(7) septic tank treatment	(8) septic tank treatment
log real net income (soles)	-0.00765	0.0108*	0.0150*	0.0132*	0.0193	0.0831**	0.0799***	0.0837***
	(0.00933)	(0.00647)	(0.00897)	(0.00766)	(0.0625)	(0.0363)	(0.0292)	(0.0287)
Obs	8812	8729	8635	8541	8812	8729	8635	8541
lag	0 year lag	1 year lag	2 year lag	3 year lag	0 year lag	1 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the state level. All outcomes are for the years 2006-2010. Mean of variable "activated sludge treatment" in 2006: 0.003. Mean of variable "septic tank treatment" in 2006: 0.075.

Table 2.11: Local Environmental Action Plan and Municipal Waste Plan, 2SLS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	local env. action plan	local env. action plan	local env. action plan	local env. action plan	municipal waste plan	municipal waste plan	municipal waste plan	municipal waste plan
log real net income (soles)	-0.0560*	-0.0114	-0.0134	-0.00344	0.0742	0.0944	0.0495	0.0664**
	(0.0318)	(0.0337)	(0.0261)	(0.0295)	(0.118)	(0.0665)	(0.0309)	(0.0310)
Obs	8629	8547	8460	8367	7397	7326	7253	7154
lag	0 year lag	1 year lag	2 year lag	3 year lag	0 year lag	1 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the state level. All outcomes are for the years 2006-2010. Mean of variable "local env. action plan" in 2006: 0.069. Mean of variable "municipal waste plan" in 2006: 0.085.

Table 2.12: Amount of Waste Collected by the Municipality (1), 2SLS

	(1) 1000 to 2999 kg	(2) 1000 to 2999 kg	(3) 1000 to 2999 kg	(4) 1000 to 2999 kg	(5) 3000 to 9999 kg	(6) 3000 to 9999 kg	(7) 3000 to 9999 kg	(8) 3000 to 9999 kg
log real net income (soles)	-0.0463	0.0176	0.0335	0.0321*	-0.0175	-0.0554**	-0.0606***	-0.0469
	(0.0401)	(0.0331)	(0.0207)	(0.0187)	(0.0342)	(0.0242)	(0.0199)	(0.0327)
Obs	8783	8701	8630	8516	8783	8701	8630	8516
lag	0 year lag	1 year lag	2 year lag	3 year lag	0 year lag	1 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the state level. All outcomes are for the years 2006-2010. Outcomes show the amount of daily waste collected by the municipality. Mean of variable "1,000 to 2,999 kg" in 2006: 0.144. Mean of variable "3,000 to 9,999 kg" in 2006: 0.102.

Table 2.13: Amount of Waste Collected by the Municipality (2), 2SLS

	(1) 50000 to 99999 kg	(2) 50000 to 99999 kg	(3) 50000 to 99999 kg	(4) 50000 to 99999 kg	(5) 100000 kg or more	(6) 100000 kg or more	(7) 100000 kg or more	(8) 100000 kg or more
log real net income (soles)	-0.00267	-0.0129	-0.0157*	-0.0165**	-0.00609	0.00460	0.0109*	0.00849
	(0.0128)	(0.0121)	(0.00813)	(0.00718)	(0.00952)	(0.00561)	(0.00576)	(0.00643)
Obs	8783	8701	8630	8516	8783	8701	8630	8516
lag	0 year lag	1 year lag	2 year lag	3 year lag	0 year lag	1 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the state level. All outcomes are for the years 2006-2010. Outcomes show the amount of daily waste collected by the municipality. Mean of variable “50,000 to 99,999 kg” in 2006: 0.016. Mean of variable “100,000 kg or more” in 2006: 0.022.

Table 2.14: Frequency of Waste Collection, 2SLS

	(1) every other day	(2) every other day	(3) every other day	(4) every other day	(5) once a week	(6) once a week	(7) once a week	(8) once a week
log real net income (soles)	0.0735*	0.0499	0.0511	0.0414	-0.0534	-0.0941*	-0.0731**	-0.0856*
	(0.0436)	(0.0574)	(0.0318)	(0.0330)	(0.0535)	(0.0522)	(0.0372)	(0.0468)
Obs	8388	8310	8244	8135	8388	8310	8244	8135
lag	0 year lag	1 year lag	2 year lag	3 year lag	0 year lag	1 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors clustered at the state level. All outcomes are for the years 2006-2010. Outcomes show the frequency of the waste collection in the municipality. Mean of variable "every other day" in 2006: 0.312. Mean of variable "once a week" in 2006: 0.320.

Table 2.15: Destination of the Collected Waste, 2SLS

	(1) open dump	(2) open dump	(3) open dump	(4) open dump
log income	12.90*	0.429	-3.464	-3.457
	(7.309)	(7.224)	(6.209)	(5.305)
Obs	7502	7425	7367	7261
lag	0 year	1 year	2 year	3 year
muni. f.e.	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the state level. All outcomes are for the years 2006-2010. Outcomes show the destination of the collected waste in the municipality. Mean of variable "open dump" in 2006: 59.81.

Table 2.16: Significant Municipality Level Results (1), 2SLS

	(1) length of health investments (months)	(2) length of health investments (months)	(3) length of health investments (months)	(4) length of health investments (months)	(5) cost of repaired roads (soles)	(6) cost of construction of rural roads (soles)
log real net income (soles)	1.732*	0.921***	1.417***	1.723***	-84575.5*	436248**
	(0.955)	(0.337)	(0.542)	(0.654)	(46819)	(182870)
Obs	2735	2683	2665	2662	7091	7040
lag	0 year lag	1 year lag	2 year lag	3 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the state level. All outcomes are for the years 2005 and 2007 - 2009. Mean of variable "length of health investments (months)" in 2005: 3.501. Mean of variable "cost of repaired roads (soles)" in 2005: 42,224. Mean of variable "cost of construction of rural roads (soles)" in 2005: 69,451.

Table 2.17: Significant Municipality Level Results (2), 2SLS

	(1) total cost of public investment	(2) total cost of public investment	(3) total cost of educ. investment	(4) total cost of educ. investment	(5) total cost of investment in transp. and com	(6) total cost of investment in transp. and com
log real net income (soles)	423789*	575972**	144162*	264422**	937791*	967592*
	(237946)	(267269)	(73699)	(115772)	(534923)	(516912)
Obs	48564	48948	9879	9926	10569	10688
lag	2 year lag	3 year lag	2 year lag	3 year lag	2 year lag	3 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors clustered at the state level. All outcomes are for the years 2005 and 2007 - 2009. Mean of variable "total cost of public investment" in 2005: 143,586. Mean of variable "total cost of educ. investment" in 2005: 74,058. Mean of variable "total cost of investment in transp. and com" in 2005: 232,803.

Table 2.18: Test of Outcomes When Producer Municipalities Are Dropped (1)

	(1) squares (m2)	(2) squares (m2)	(3) squares (m2)	(4) squares (m2)	(5) activated sludge	(6) activated sludge	(7) activated sludge	(8) septic tank
log real net income (soles)	4222*	14141**	7227*	5167**	0.0118*	0.0153*	0.0136	0.0849**
	(2268)	(6239)	(4045)	(2383)	(0.00688)	(0.00906)	(0.00832)	(0.0396)
Obs	6408	6501	6501	6501	8411	8322	8233	8411
lag	2 year lag	3 year lag	3 year lag	3 year lag	1 year lag	2 year lag	3 year lag	1 year lag
muni f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Income is the real net municipality income. Standard errors clustered at the state level. Outcomes in columns (1)-(4) are for the years 2005 and 2007 - 2009, outcomes in columns (5)-(8) are outcomes for the years 2006-2010.

Table 2.19: Test of Outcomes When Producer Municipalities are Dropped (2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	septic tank treatment	septic tank treatment	local env. action plan	municipal waste plan plan	1000 to 2999 kg	3000 to 9999 kg	3000 to 9999 kg	50000 to 99999 kg
log real net income (soles)	0.0767**	0.0786**	0.0595*	-0.0625*	0.0290	-0.0578**	-0.0544**	-0.0167*
	(0.0311)	(0.0315)	(0.0362)	(0.0347)	(0.0216)	(0.0274)	(0.0229)	(0.00868)
Obs	8322	8233	6882	8314	8208	8384	8317	8317
lag	2 year lag	3 year lag	0 year lag	3 year lag	3 year lag	1 year lag	2 year lag	2 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Income is the real net municipality income. Standard errors clustered at the state level. All outcomes are for the years 2006-2010.

Table 2.20: Test of Outcomes When Producer Municipalities Are Dropped (3)

	(1) 50000 to 99999 kg	(2) 100000 kg or more	(3) every other day	(4) once a week	(5) once a week	(6) once a week	(7) open dump (pct)
log income	-0.0187**	0.00830	0.0751	-0.106**	-0.0827**	-0.102**	15.47**
	(0.00802)	(0.00683)	(0.0483)	(0.0527)	(0.0387)	(0.0507)	(7.477)
Obs	8208	8317	8075	8000	7938	7833	7213
lag	3 year lag	2 year lag	0 year lag	1 year lag	2 year lag	3 year lag	0 year lag
muni. f.e.	Y	Y	Y	Y	Y	Y	Y
year f.e.	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Income is the real net municipality income. Standard errors clustered at the state level. All outcomes are for the years 2006-2010.

Chapter 3

Food Borne Disease Outbreaks, Consumer Purchases and Product Preferences: The Case of the 2010 Salmonella Egg Outbreak in the U.S.[1]

[1]This essay is joint work with Sofia Berto Villas-Boas. Chantal Toledo is very grateful to Meredith Fowlie and Peter Berck for their constant support and guidance. We thank Lydia Ashton, François Gerard and participants at the Environmental and Resource Economics Seminar at UC Berkeley for helpful comments. Financial support from the Giannini Foundation of Agricultural Economics via a 2012-2013 grant is greatly appreciated. All errors are our own.

3.1 Introduction

When making purchasing decisions about products, consumers traditionally include factors such as price, quality and availability of substitutes. It is less clear what happens when a very similar product is removed from the market for safety reasons. On the one hand, if a product with security concerns is removed from the market and the remaining products experience additional security checks, consumers may perceive the market as being at least as secure as before. On the other hand, if the removal of the unsafe product provides negative information about closely related products or an industry as whole, consumers may respond by decreasing demand, even in the absence of security concerns about the remaining products. The empirical question is whether a recall of an unsafe product can have a direct impact on consumer purchases and preferences, even if the remaining products are safe. From a safety perspective, the question is relevant if firm incentives to invest in risk reduction and regulatory compliance in existing regulation depend, to some degree, on consumer responses to recalls.

In May 2010, the Center for Disease Control and Prevention (CDC) identified a nationwide, four-fold abnormal increase in the number of reported Salmonella infections. Three months later, on August 13, 2010, a first egg farm, located in Iowa, conducted a nationwide voluntary recall of around 228 million eggs. By August 18, 2010, the same farm expanded its recall to around 152 million additional eggs. Within 48 hours, on August 20, 2010, a second egg farm conducted another nationwide voluntary recall of around 170 million eggs. In total, from August 13 to August 20, 2010, more than 500 million eggs were recalled, in what would be the largest egg recall in U.S. history. Infected eggs from these two major egg producers were distributed in fourteen U.S states, among which was California. Eggs were recalled using specific plant numbers and codes that allowed tracing back to the box level, leaving no infected eggs in stores. Consumers and stores could return infected eggs for a full refund, with or without receipt. The three egg recalls received extensive national and local media coverage on the television, radio, newspapers and the internet. Media interest persisted over a 6 week period following the event, in particular covering farm inspections that found numerous violations and showed that the egg farms were infested with flies, maggots, rodents and overflowing manure pits, as well as the testimony of both farm owners in Congress about the outbreak. The fact that there were three consecutive egg recalls within one week could have led consumers to think that this was a major outbreak, and not a regular food recall. Furthermore, given the information provided by the media coverage, some consumers may have obtained information or updated their beliefs on the egg industry as a whole. If consumers were perfectly informed, did not update their beliefs, and expected no further recalls, we could anticipate no effect of the event on consumer purchases. However, if consumers did not have perfect information on the outbreak or the recall codes, updated their beliefs about the egg industry, or "over-reacted" to the recalls, we could expect a drop in egg purchases following the event, at least temporarily. We find that the latter was true.

Using a unique product-level scanner data set of a national grocery chain that has stores in both high and low income zip codes, we examine how consumers in the United States reacted to the three consecutive egg recalls. First, we test whether consumers changed their egg purchases in California following the recalls. We examine media coverage on the highly publicized outbreak and hypothesize that media coverage is the channel through which consumers became informed about the event. Second, we study whether consumers substitute away from conventional eggs towards other types of specialty "greener" eggs that may be perceived as having a lower probability of Salmonella, such as organic or cage free eggs. We hypothesize two possible results for purchases of unaffected eggs. On one hand, consumers might substitute away from conventional types of eggs to non-conventional specialty eggs (a substitution effect within egg classes). On the other hand, some consumers might choose to reduce all egg purchases, leading to a decline in purchases of all types of eggs. Third, we investigate whether different socio-economic groups reacted differently to the egg recalls. In particular, we look at whether income and household size affect the response to the recalls. To do this, we use demographic data for the zip code where the store is located. Income may affect the response if wealthier consumers are able to substitute to greener alternatives, which can cost up to twice as much as traditional shell eggs. Finally, we examine whether separate areas within California reacted differently to the egg recalls. Due to its distribution system, our national grocery chain had infected eggs only in Northern California and not in Southern California. We use variation within California to test whether consumers in Southern California reduced egg purchases as well.

We perform a difference-in-difference analysis of the recalls and use a control state that did not receive infected eggs, Washington. We are also able to control for seasonality (i.e., seasonal changes that could be occurring at the time of the event in California) by using data from previous years around the event date. We use the fact that infected eggs could be traced to the box level to establish a clear definition of the treatment and follow a panel of over 600 stores during a 4 year period. Further, given the geographical distribution of infected eggs, we are able to measure potential spillovers to unaffected areas of California.

We find a 9 percent reduction in egg sales in California following the three egg recalls. Given an overall price elasticity for eggs in U.S. households of -0.1, this sales reduction is comparable to an almost 100% increase in prices.[2] We find that this decrease in sales was driven by a drop in purchases of traditional large shell eggs and find no evidence of substitution toward other greener type of eggs such as organic or cage free eggs. We also find no correlation with demographics such as income, but we do find that areas that had a larger than average household size decreased egg purchases more. We also find differentiated effects among Northern and Southern Californian stores. Although the national grocery chain had infected eggs only in Northern California, we find that Southern Californian stores had lower egg sales as well. The overall sales reduction in

[2]We formally test whether, in our national grocery chain, price responded to the event. We find that, due to its pricing system, the national grocery chain did not adjust price. We estimate the effect with and without prices and find very similar results.

Southern California was half as large as the reduction in Northern California, and is consistent with media and reputation effects being significant determinants of demand, even in the absence of an actual food recall in a region.

This paper contributes to the existing literature in the following ways. First, this research contributes to the empirical evidence on the effects of food-safety related information on consumer demand and preferences. These studies have found large and significant effects of warnings about mercury on fish consumption (Shimshack et al., 2007), BSE announcements on beef sales and demand (Crowley and Shimazaki, 2005; Schlenker and Villa-Boas, 2009; Burton and Young, 1996), and milk bans (Smith et al.,1988). In this study, we use a unique scanner level data set from one of the largest grocery chains, use store-by-product-by-year fixed effects to pick up location-specific shifts in consumption patterns and include socioeconomic data that allow for the estimation of heterogeneous treatment effects. The closest study to ours is Schlenker and Villa-Boas (2009). In that study, the authors examine how consumers and financial markets in the United States reacted to two health warnings about mad cow disease and find a large (around 20%) and significant reduction in beef sales following the first discovered infection. The effect dissipates slowly over the next three months. This study contributes to the literature by providing evidence on consumer responses to a highly publicized food borne disease outbreak using detailed purchasing data from a large scanner data set. Furthermore, given the important amount of revenues at stake and state-wide initiatives such as Proposition 2,[3] the egg market is of particular interest to consumers, producers and policy makers. This study realtes to the literature analyzing the effect of health information on egg consumption ((Chang and Just, 2007), (Brown and Schrader, 1990), (Yen et al., 1996)) and the impact of non conventional egg production in terms of costs, benefits and price elasticities ((Sumner et al., 2008), (Lusk, 2010), (Greene and Cowan, 2012)).

Second, this study provides insights on geographic spillover effects of recalls. Freedman, Kearny and Lederman (2012) examine consumer demand for toys following the discovery of high levels of lead content in certain toys and find evidence of sizable spillover effects of product recalls to non-recalled products and non-recalled manufacturers. Cawley and Rizzo (2008) find spillover effects in a case of withdrawal of a drug from the market, as do Reilly and Hoffer (1983) in a study on automobile recalls. This study exploits an unusual situation in our national grocery chain, where only stores in the Northern California division had infected eggs and stores in the Southern California division did not, and finds evidence of geographical spillovers.

[3]Proposition 2 was a California ballot proposition in the general election of November 4, 2008. It passed with 63% of the votes in favor and 37% against. Proposition 2 requires that calves raised for veal, egg-laying hens and pregnant pigs be confined only in ways that allow these animals to lie down, stand up, fully extend their limbs and turn around freely. Exceptions are made for transportation, rodeos, fairs, 4-H programs, lawful slaughter, research and veterinary purposes. It also provides misdemeanor penalties, including a fine not to exceed $1,000 and/or imprisonment in jail for up to 180 days. The main portion of the statute will become operative on January 1, 2015 and farms have until that date to implement the new space requirements for their animals.

Third, this paper relates to the empirical literature that investigates the effects of government-mandated information disclosure programs on consumer and firm behavior. Studies have shown significant effects of government-mandated information disclosure programs such as restaurant hygiene grade cards (Jin and Leslie, 2003), nutritional labeling requirements (Mathios, 2000), SEC financial disclosure requirements (Greenstone, Oyer, and Vissing-Jorensen, 2006), environmental safety contexts (Bennear and Olmstead, 2008) and toy products (Freedman, Kearny and Lederman, 2012). This paper contributes to this literature by providing evidence of the effects of government-induced[4] recall information using a product that could be clearly traced to the box level and detailed purchasing data.

The remainder of this paper is organized as follows. The next section provides a brief background on current egg production methods, Salmonella and the 2010 Salmonella egg outbreak. Section 3 outlines our data and section 4 describes the model. Section 5 presents our empirical results and section 6 concludes.

3.2 Background

3.2.1 "An Egg is No Longer an Egg"

According to the American Egg Board, in 2010, the per capita consumption of eggs in the U.S. was 248 eggs per year.[5] Eggs are one of the most inelastic products in the U.S., with a price elasticity of demand of -0.1.[6] The five largest egg producing states have 50% of all U.S. layers (IA, OH, PA, IN, CA). Although eggs are currently produced under a variety of production methods, 95% of the egg production in 2010 came from conventional battery cages. Conventional battery cages are stacks of cages that can be up to two stories high and keep about six hens to a cage. Each hen gets up to 67 square inches of floor space (about ¾ of a sheet of notebook paper). Hens are unable to stretch their wings and have no access to natural light. According to the United States Department of Agriculture (USDA), as many as 100,000 birds may be grouped together under a single roof. The remaining 5% of egg production comes from production methods that are classified by how eggs are raised (e.g, cage free, free range, pasture-raised)[7] and/or by what birds are

[4]Although the egg farms launched the three voluntary recalls, media reports and Congressional testimony have cited pressure from government institutions to undertake these recalls.

[5]Per capita consumption is a measure of total egg production divided by the total population. It does not represent demand.

[6]See Krugman and Wells (2009).

[7]For example, for an egg to be labeled "cage free" hens must have been kept out of cages and had continuous access to food and water, but not necessarily access to the outdoors. The label "free range" means that, in addition to meeting the cage-free standards, the birds must have continuous access to the outdoors, unless there is a health risk present. However, there are no standards for what that outdoor area must be like. "Pasture - Raised" implies that hens got at least part of their food from foraging on greens and bugs, which adherents say can improve flavor, but there is no federal definition for this label. There are also several animal care labels but they are not harmonized.

fed (e.g., organic, vegetarian-fed, no hormones, no antibiotics).[8] A single egg box usually contains more than one label (for example, “Cage Free, Kosher and Vegetarian-fed hens”). The USDA shield can be found on about 35 percent of eggs in the market and certifies that the agriculture department is auditing the producers at least once a year to verify that their claims are true. The USDA’ s rules apply only to eggs with the department’s shield. For eggs that are not a part of its grading program, either state rules apply or the use of the label is unregulated. Finally, there are also different egg grades (grades AA, A or B), which depend mainly on the firmness of the whites.

3.2.2 Salmonella

Salmonellosis is an infection caused by a bacteria called Salmonella. It is one of the most common causes of food poisoning in the United States. Salmonella is spread through food (contaminated eggs, poultry, meat, unpasteurized milk or juice, cheese, contaminated raw fruits and vegetables, spices, nuts) and animals (particularly snakes, turtles, lizards, frogs, birds and pet food and treats). Salmonella is killed by cooking and pasteurization. Most people infected with Salmonella develop diarrhea, fever, and abdominal cramps 12 to 72 hours after infection. The illness usually lasts 4 to 7 days, and most people recover without treatment, but some infected individuals need to be hospitalized. Salmonella infections can cause severe illness and death. The elderly, infants, and those with impaired immune systems are most at risk. An estimated 1.4 million cases occur annually in the United States. Of these, around 40,000 are culture - confirmed cases reported to the CDC and around 400 cases per year are fatal. A small number of infected people develop Reiter’s Syndrome, which can lead to arthritis, and is a potential long term effect of Salmonella. According to the CDC, Salmonella was the top pathogen contributing to domestically acquired food borne illness resulting in hospitalization and death in the United States in 2011. Studies in the United States have produced mixed evidence on the link between the type of egg (e.g., battery cage, cage free, free range, organic) and the probabilities of Salmonella infection; having confounding factors such as production size and age of the farm.[9] Evidence shows that Salmonella spreads through livestock animals (especially when kept in large numbers in confined spaces), runoff from livestock pastures, and leaky or over-topped waste lagoons at industrial farming sites.

[8]For example, the USDA “organic” label requires that birds must be kept cage free with outdoor access (although the time and the type of access are not defined), they cannot be given antibiotics (even if ill) and their food must be free from animal byproducts and made from crops grown without chemical pesticides, fertilizers, irradiation, genetic engineering or sewage sludge. If an egg box labeled as organic does not have the program’s label, it may be part of an independent or state-run program. The USDA grade shield “vegetarian-fed” certifies that the eggs came from hens raised on all-vegetarian feed (as opposed to animal by-products that can be included in conventional chicken feed).

[9]In January 2012, battery cages were banned in the European Union due to welfare concerns.

3.2.3 The 2010 Salmonella Egg Outbreak and Egg Recall

From May 1 to November 30, 2010, the CDC observed a nationwide, four-fold increase (1939 illnesses) in the number of Salmonella incidents reported. Figure 3.1 in the appendix shows an epidemic curve of the number of Salmonella Enteritidis cases matching PFGE (Pulsed-Field Gel Electrophoresis) patterns for the year 2010. The curve shows an increase in reports beginning in May, peaking in July, and returning to baseline in November. From August 13 to August 20, 2010, more than 500 million eggs (around 0.7 % of production or 0.55 billion out of 80 billion/year) were recalled after dangerous levels of Salmonella were detected, in what would be the largest egg recall in U.S. history. Infected eggs were distributed in fourteen U.S states (AR, CA, IA, IL, IN, KS, MN, MO, NE, ND, OH, SD, TX, and WI). On August 13, 2010, Wright County Egg of Galt, Iowa, conducted a nationwide voluntary recall of around 228 million eggs. Five days later, on August 18, 2010, Wright County Egg expanded its recall to around 152 million additional eggs. Two days later, on August 20, 2010, a second producer, Hillandale Farms of Iowa, conducted a nationwide voluntary recall of around 170 million eggs. Infected eggs in all 14 states were recalled using codes clearly labeled on the egg box. Consumers and stores could return eggs for a full refund. Infected eggs were recalled using specific plant numbers and codes that allowed tracing back to the box level. For example, the first recall (08/13/2010) had Julian dates[10] ranging from 136 to 225 and plant numbers 1026, 1413 and 1946. They were packaged under different brands and carton sizes (6 - egg, dozen, 18 - egg). Figure 3.2 shows an example of how infected eggs were identified using codes labeled on the egg box.

The three egg recalls linked to the 2010 Salmonella egg outbreak received extensive national and local media coverage on the television, radio, newspapers (e.g., San Francisco Chronicle, Los Angeles Times, New York Times, Washington Post) and the internet. In August 2010, the media reported on an inspection conducted by the U.S. Food and Drug Administration (FDA) showing that barns of the two egg producers (Wright County Egg and Hillandale Farms) were infested with flies, maggots and rodents and had overflowing manure pits. In September 2010, the media undertook extensive coverage of the owners of both farms testifying before Congress about the outbreak.[11] To measure media coverage of the event, we conducted a Lexis-Nexis search which gave us the daily count of articles that appeared on the 2010 Salmonella egg outbreak, starting 15 days before the event up to 60 days after the event. Figure 3.3 shows the number of articles in major newspapers that include the words "Salmonella" and "Eggs" on a given day. The first egg recall (August 13, 2010) seemed to pass relatively unnoticed by the media while the second and third egg recalls (August 18 and August 20, 2010) received considerably more attention.

[10]Julian dates are the numeric date of the year that the eggs were cartoned. For example, eggs that were cartoned on January 1 have a "001" printed on them and eggs cartoned on December 31 have a 365, the 365th day of the year.

[11]One farm owner testified and the other farm owner cited his Fifth Amendment right against self-incrimination and did not answer questions.

Attention remained relatively high and peaked around five days after the third egg recall. It decreased until the media coverage of the farm inspection conducted by the USDA, when it increased again. Newspaper coverage then decreased considerably, until Congress released the results of investigations and both farm owners appeared before Congress. Thus, in total, media coverage lasted until around forty days after the event, peaking around specific events linked to the outbreak. In light of this media coverage, the clear tracing back of infected eggs to the box level and the fact that both consumers and stores could return infected eggs for a full refund, we proceed to test empirically whether this Salmonella egg outbreak still had an impact on consumer purchases.

3.3 Data

We use a unique scanner data set from one of the largest U.S. grocery chains to estimate the impact of three egg recalls on consumer purchasing decisions. This chain has a presence in both high and low income zip codes throughout California and Washington, and is a full-service neighborhood grocery store. Our data set includes a balanced panel of 654 stores. Of these 654 stores, 490 stores are in California, one of the fourteen states that had infected eggs, and 164 stores are in Washington, one of the states that did not have infected eggs.[12] Observations in this data set are daily sales at the product and store level, e.g., Store 91 sold 1 box of Large Eggs AA of a particular brand for a total of $2.69 on August 12, 2008, where a product is represented by a unique Universal Product Code (UPC). The data set includes all egg sales and encompasses a number of sub-categories, among which are organic and cage free eggs. Data are for the period July 15 through September 18 in the years 2007, 2008, 2009 and 2010, thus spanning the period 4 weeks prior to and 4 weeks past the "event week." The event week is defined as the week from August 13 to August 20, since this is the time window during which the 3 egg recalls took place in 2010. The scanner data report both sales revenues and quantity sold, and we are therefore able to construct the price by dividing sales revenue by quantity for each observation.

Prices are fixed for seven days from Wednesday to the next Wednesday when new promotional flyers are printed and distributed. The summary statistics are given in table 3.1. Closely related products (e.g., Large Eggs and Extra Large Eggs of a certain brand) can have various UPCs, and thus we use several measures to aggregate sales and quantity sold of comparable products for a given day and store. The variable subclass groups together UPCs with closely comparable product characteristics, e.g., all "Eggs Large A", or "Eggs Large AA." The next aggregation level is an egg class which groups similar egg types together, e.g., all "Traditional Shell Eggs," or "Value Added Specialty Eggs." Egg products are furthermore grouped into categories; here we only use shell eggs which

[12] Although a very small proportion of infected eggs might have reached the state, all the major sellers in WA said they did not have infected eggs, including our national grocery chain.

account for 97% of all egg sales.[13] For example, when we use the category aggregation measure, we add all purchases of shell eggs. The data set contains 7 subclasses, 2 classes and 1 category.

We obtain the exact location for each of the 654 stores and are able to match the location with socio-economic statistics from the 2000 U.S. Census based on the zip code in which a store is located. Summary statistics of the socio-economic variables are given in table 3.1.

3.4 Analytical Framework

In order to estimate the abnormal change in purchases after the three egg recalls, we use a difference-in-difference approach. We consider a "treatment" state, California, which had infected eggs distributed in its stores, and a "control" state, Washington, which did not have infected eggs distributed in its stores. We also use observations for the same months in previous years to control for seasonal changes that could be occurring at the time of the event date in California.

The baseline reduced form econometric model we use for estimating the effect of the three egg recalls is:

$$y_{asnt} = \alpha_{ast} + \beta_{1,n} I_n + \beta_{2,n} I_n I_{CA} + \gamma P_{asnt} + \delta_{1,n} I_{n,event} + \delta_{2,n} I_{n,event} I_{CA} + \varepsilon_{asnt} \tag{3.1}$$

where y_{asnt} is the log of quantity sold by aggregation level a (e.g., category, class, subclass) in store s in month n of year t, α_{ast} is an aggregation level by store by year fixed effect, I_n is an indicator variable equal to one if the purchase occurred in a post-event "month" (i.e., 4 weeks after the "event week" of August 13 to August 20, 2010), I_{CA} is a dummy equal to one if the purchase occurred in California, P_{asnt} is the log of the *average* price of all products in aggregation level a in store s in month n of year t, $I_{n,event}$ is a dummy variable equal to one if the purchase occurred in the post-event "month" (one month after August 20, 2010) and ϵ_{asnt} is an error term. The fixed effects α_{ast} allow for shifts of the average purchases by stores s, aggregation levels a and period t due to, for example, trends in buying habits by products between stores and years. The coefficient $\beta_{1,n}$ picks up seasonal effects following month n and the coefficient $\beta_{2,n}$ captures the *additional* effect in California. To address potential concerns about temporal correlation across months (such as weather shocks, for example), we include only one observation before the event and one after (N=1).[14] We also control for the log of the average price of all products in aggregation level a in store s in month n of period t, P_{asnt}, and show in a separate regression that prices did not respond to the event. The coefficient $\delta_{2,n}$

[13]The remaining 3% of eggs in our sample are liquid eggs.

[14]Bertrand et al. (2004) show that auto-correlation can give incorrect estimates of the error term and reject the null hypothesis too often if several pre-event and post-event months are included.

estimates the treatment effect. The treatment effect comes from abnormal changes in egg purchases in month n in the event period in California, in addition to the seasonal effect captured by $\beta_{1,n}$ and $\beta_{2,n}$ and in addition to the trend in Washington, captured by $\delta_{1,n}$. Finally, to address potential issues of contemporaneous correlation of purchases in a given month and region, we cluster the error terms ϵ_{asnt} at the month by division (Northern CA, Southern CA, Seattle and Portland metropolitan area) level.

The identification in this analytical framework comes from comparing changes within aggregation levels and stores in the event year, controlling for seasonality effects. In particular, we will estimate the seasonal difference in purchasing behaviors in a year (i.e., by how much are sales in the post-event month higher than in the previous month) and compare the difference to the result obtained in other years. We include years before the event year in order to obtain an estimate of the seasonality components $\beta_{1,n}$ and $\beta_{2,n}$. In a robustness check, we also estimate abnormal changes in egg purchases without the seasonal components and find similar results.

Controlling for seasonality effects, we hypothesize that egg purchases may be lower in California after the three egg recalls ($\delta_{2,n} < 0$). We also consider the possibility of substitution effects. It is possible that some consumers do not decrease overall egg purchases but rather substitute from certain egg classes (traditional) to other classes (value added specialty eggs) if they think these type of eggs have a lower probability of having Salmonella. We formally test this hypothesis and estimate model (3.1) for each separate subclass.

We then test whether responses to the three egg recalls differ by socio-economic groups and include interaction effects for income and household size with the abnormal change. The estimated regression used to test this possible effect is:

$$\begin{aligned} y_{asnt} = \alpha_{ast} + \beta_{1,n} I_n + \beta_{2,n} I_n I_{CA} + \gamma P_{asnt} + \delta_{1,n} I_{n,event} + \delta_{2,n} I_{n,event} I_{CA} \\ + \lambda_{1,n} I_n C_s + \lambda_{2,n} I_n I_{CA} C_s + \theta_{1,n} I_{n,event} C_s + \theta_{2,n} I_{n,event} I_{CA} C_s + \varepsilon_{asnt} \end{aligned} \tag{3.2}$$

The first line is the same as in the main specification (model 3.1) and the second line includes the interactions of interest. In particular, C_s is the demeaned socio-economic characteristic of the zip code in which store s is located; $\lambda_{1,n}$ and $\lambda_{2,n}$ allow the seasonality components $\beta_{1,n}$and $\beta_{2,n}$ to be different by socio-economic subgroups; and our coefficient of interest $\theta_{2,n}$, captures whether the abnormal change in California differs by socio-economic characteristics. In this specification, we test whether the effect of the recalls differed by income and household size.

Finally, we exploit an unusual situation in our national grocery chain, where only stores in the Northern California division had infected eggs and stores in the Southern California division did not. Thus, we now consider two treatment areas, Northern California, which had infected eggs, and Southern California, which did not have infected eggs but may have experienced decreased egg sales as well due to the media coverage and the unclear geographical distribution of infected eggs. In this specification, Washington is still our control state. The estimated regression used to test this possible effect by Californian geographical divisions is:

$$y_{asnt} = \alpha_{ast} + +\beta_{1,n} I_n + \beta_{2,n} I_n I_{NorthernCA} + \beta_{3,n} I_n I_{SouthernCA} + \gamma P_{asnt} \\ +\delta_{1,n} I_{n,event} + \delta_{2,n} I_{n,event} I_{NorthernCA} + \delta_{3,n} I_{n,event} I_{SouthernCA} + \varepsilon_{asnt} \quad (3.3)$$

where the additional effect for California from model (3.1) is allowed to vary by whether stores are in Northern California or Southern California.

3.5 Empirical Results

3.5.1 Changes in Egg Sales

We begin by exploring whether there are any differences in monthly egg sales over the four years of data by comparing the treatment stores (stores in California) and the control stores (stores in Washington). Figure 3.4 plots the evolution of monthly average egg purchases during the 2007-2010 period, using the raw data and no controls. Monthly average egg purchases are shown using various aggregation measures for both treatment and control stores. The top panel aggregates egg purchases at the category level, the middle panel aggregates egg purchases at the class level and the bottom panel aggregates egg purchases at the subclass level. All panels show similar downward parallel trends between California and Washington stores.[15] Variations in egg sales are larger in California than in Washington but sales are also higher in magnitude. A potential concern is that reduced egg sales in the post-event month in 2010 were merely the consequence of broader adjustments in consumer purchasing behavior during this time period. For example, consumers may have purchased fewer eggs during that time of the year due to macroeconomic conditions or changes in trends in buying habits of individual products between years in each store. To investigate this issue, figure 3.5 shows the evolution of daily sales around the "event week" (August 13 to August 20, 2010) in California. Figure 3.5 switches the time scale to the daily level and plots changes in log egg purchases (in quantities of egg boxes sold) under category, class and subclass aggregations for stores in California only. It plots data starting 30 days before the "event day" (here defined as August 13, 2010, the day of the first egg recall) up to 35 days after the event day. Abnormal changes are net of price, store-by-aggregation fixed effects and weekday fixed effects (sales are always higher on weekends). Egg sales show a large drop a few days after the first recall and a small increase between the second egg recall and the third recall. Sales reach their lowest level in the time period around 11 days after the first egg recall.

[15] There is a downward trend of egg consumption in the United States. However, there is still a debate on how long this trend will last. For example, FAPRI (2008) projects a decrease of per capita egg consumption by 5 eggs per year or 1.9 % until 2017, while USDA (2008) expects a downward trend until 2012 and an increase from then on until 2017.

This suggests that, if egg purchases decreased due to the egg recalls, there was a small (days) time-lag between the time the recalls were made and the time that the effect was reflected in lower purchases in stores.

3.5.2 Analysis of Monthly Egg Purchases

We proceed by testing whether there are any abnormal changes in egg purchases following the three egg recalls, where the "event week" is defined as the week from August 13, 2010 to August 20, 2010. The dependent variable is the log of egg purchases (in egg boxes). All regressions include aggregation level-by-month-by-year fixed effects and month fixed effects to account for seasonal purchasing patterns. Table 3.2 shows the results for different aggregation levels of egg purchases. Column (1) shows the results when egg sales are aggregated at the category level (shell eggs), column (2) when they are aggregated at one class level (Traditional Shell Eggs) and column (3) when they are aggregated at another class level (Value Added Specialty Eggs). Because local events and habits may lead to correlated error terms for a given month, we cluster error terms at the division-by-month level. We include one observation before and one after the event date where the 4 week period following the event week is labeled "Event". The row "Event * CA" shows our coefficients of interest, the additional abnormal change in California. The price elasticity is given by "Log Price," where price is the average price of the corresponding aggregation level. Robust standard errors are reported in parentheses. Column (1) shows that egg purchases decreased by around 9 percent in the first month following the three egg recalls in California (significant at the 5% level). The price elasticity for shell eggs is -0.05 but is not significant. Column (2) shows that, when purchases are aggregated at the "Traditional Shell Eggs" class level, sales are still around 9 percent lower in California than in Washington. The effect is significant at the 5% level. The price elasticity for shell eggs is -0.08 but still not significant. Column (3) aggregates purchases at the "Value Added Specialty Eggs" class level and shows a decrease of around 10 percent, significant at the 10% level. Demand becomes slightly more elastic in columns (2) and (3) because there are more possibilities of substitution between classes but demand remains largely inelastic and not significant.

3.5.3 Heterogeneous Effects

3.5.3.1 Analysis of Monthly Egg Purchases by Types of Eggs

Although egg sales decreased on average, consumers may have substituted away from traditional shell eggs toward other type of greener eggs. Although greener eggs, such as organic or cage free eggs, have a higher price than traditional shell eggs, consumers may have substituted toward these type of eggs if, for example, they thought that they had a lower probability of having Salmonella. We proceed by formally testing whether there are any substitution effects toward these types of eggs. Table 3.3 shows the results of regressions that test the effect of the event month in California for each egg subclass. Columns (1) - (3) test the effect on "Traditional" eggs (large, extra large and jumbo) and columns (4) - (7) test the effect on "Value Added Specialty Eggs" (brown, organic, cage free and nutrient enhanced). Column (1) shows that purchases of large traditional shell eggs decreased by 10 percent in California in the month following the event week (significant at the 5% level). This is the only significant decrease at the subclass level and this result shows that the effect was largely driven by the decrease in purchases of large traditional shell eggs. Large traditional eggs represented 79 % of sales in our sample in 2009. Table 3.3 shows lower sales for jumbo, brown, cage free and nutrient enhanced eggs but the results are not significant. Sales for extra large traditional shell eggs and for organic eggs seem higher but the results are not significant. The price elasticity for extra large, brown, cage free and nutrient enhanced is greater than the overall subclass elasticity. Large, jumbo and organic eggs seem to have more inelastic demands.

Given this decrease in egg purchases, price could have responded in either of two ways. Price can decrease if sellers hope to increase demand by lowering egg prices. On the other hand, price can also increase if the egg recalls caused a shortage of eggs. To test whether the event had an effect on prices at our national grocery chain, columns (1) - (4) in table 3.4 formally test the effect of the event on price. Given the results from tables 3.2 and 3.3, we focus the analysis on the overall category level, on both classes and on the subclass "Large Traditional Shell Eggs." Columns (1) - (3) in table 3.4 show no statistically significant response of prices in California for overall shell eggs, traditional eggs or specialty eggs. Column (4) shows a 12 percent increase in price for the subclass "Large Traditional Shell Eggs." In columns (5) - (8) we repeat the analysis on quantities from tables 3.2 and 3.3 but do not control for price. The estimated coefficients for all regressions are very similar and statistically indistinguishable from when we include price.[16]

3.5.3.2 Heterogeneous Effects by Demographics

Previous studies such as Schlenker and Villas-Boas (2009), Burton et al. (1996) and Shimshack et al. (2007) have found heterogeneous responses by socio-economic groups. In this section, we test whether egg purchases following the egg recalls decreased in a differentiated way based on income and household size. To do this, we match each grocery store with the socio-economic characteristics of the zip code in which it is located. Table 3.5 shows the results for the overall shell eggs category, the traditional shell eggs class and the large traditional shell eggs subclass. Income is the demeaned average income in the zip code in which the store is located (in 10,000 USD) and HH Size is the demeaned average household size in the zip code in which the store is located. Socio-economic data come from the 2000 U.S. Census. Given previous results, we now focus the analysis on the overall shell eggs category, the traditional shell eggs class and the large traditional shell eggs subclass. Columns (1) - (3) show that stores in California that are located in zip codes with higher median income did not have significantly different purchasing behavior.

[16]This is consistent with the price elasticity of demand for eggs being -0.1 in the U.S.

However, stores in California that are located in zip codes with a higher average household size show significantly larger drops, 19 percent less for each additional household member. A caveat to the results is that it is possible that more affluent customers diverted egg purchases to farmers' markets or high-end grocery stores after the egg recalls and thus the estimates would suffer from selection bias. The data allows only for the identification of effects with purchases undertaken at the national grocery chain.

3.5.3.3 Heterogeneous Effects by Geographical Divisions

In our previous sections, we considered California as our "treatment" state and Washington as our "control" state. In this section, we exploit the fact that only stores in the Northern California division of our national grocery chain had infected eggs and that stores in the Southern California division did not. We consider two "treatment" areas, Northern California and Southern California. We hypothesize that it is possible that stores in Southern California had drops in egg purchases although they did not have infected eggs themselves due to, for example, updating of beliefs or media exposure. We formally test this hypothesis in table 3.6. Column (1) shows that when egg purchases are aggregated at the category level, egg purchases significantly decreased by 12 percent in the Northern California division and by 5 percent in Southern California. Column (2) shows that when egg purchases are aggregated at the traditional shell eggs class level, egg purchases decrease by around 14 percent in Northern California and by 6 percent in Southern California stores. Finally, column (3) shows that, when egg sales are aggregated at the large traditional shell eggs subclass level, egg purchases decrease by 15 percent in Northern California and by 6 percent in Southern California stores. Table 3.6 shows that sales reductions in Southern California were around half as large as those in Northern California. Media coverage and updating of beliefs could have led to the drop in Southern California stores. This finding is similar to Schlenker and Villas-Boas (2009), who found that media coverage can have significant demand effects. Schlenker and Villas-Boas (2009) focus on mad cow and find that coverage by a popular TV show resulted in futures price drops of more than 50% of the drop observed following the first discovery of an infected cow.

3.5.4 Robustness Checks

In this section, we perform a series of robustness checks. First, we test the sensitivity of the baseline results to various assumptions about the seasonality parameters. If there is a sales spike or drop in one of the pre-event periods (2007, 2008 or 2009) due to another cause, our seasonality components may be biased. Columns (1) - (4) in table 3.7 use the main specification (model 3.1) but estimate the effect of the three egg recalls using only the years 2009 and 2010. By using only one pre-treatment year, we do not control for the pre-event trend. We find that the results for the overall eggs category, the Traditional Shell Eggs class and the Large Traditional Shell Eggs subclass are very similar to the ones obtained in tables 3.2 and 3.3. The results for Value Added Specialty Eggs are substantially smaller and not significant. Columns (5) - (7) replicate the results from table 3.2 at the category level only (overall shell eggs) but exclude one of the control periods. Column (5) drops the year 2007, column (6) drops the year 2008 and column (7) drops the year 2009. Table 3.7 shows that excluding the years 2007 and 2008 gives very similar results, a 7 percent decrease in egg purchases. However, excluding the year 2009 shows a larger drop: an 11 percent decrease. Overall, the results seem robust to assumptions about the seasonality components.

Second, we test the sensitivity of the baseline results by using Washington as a control state. Columns (1) - (4) in table 3.8 exclude data from Washington and use stores in Southern California as controls. The rationale is that we may assume that stores in Southern California have similar trends to stores in Northern California. We find that, for all aggregations (category, class and Large Traditional Shell Eggs subclass), the results are similar to those in the main specification: a significant 7 percent to 9 percent drop in egg purchases, depending on the aggregation level.

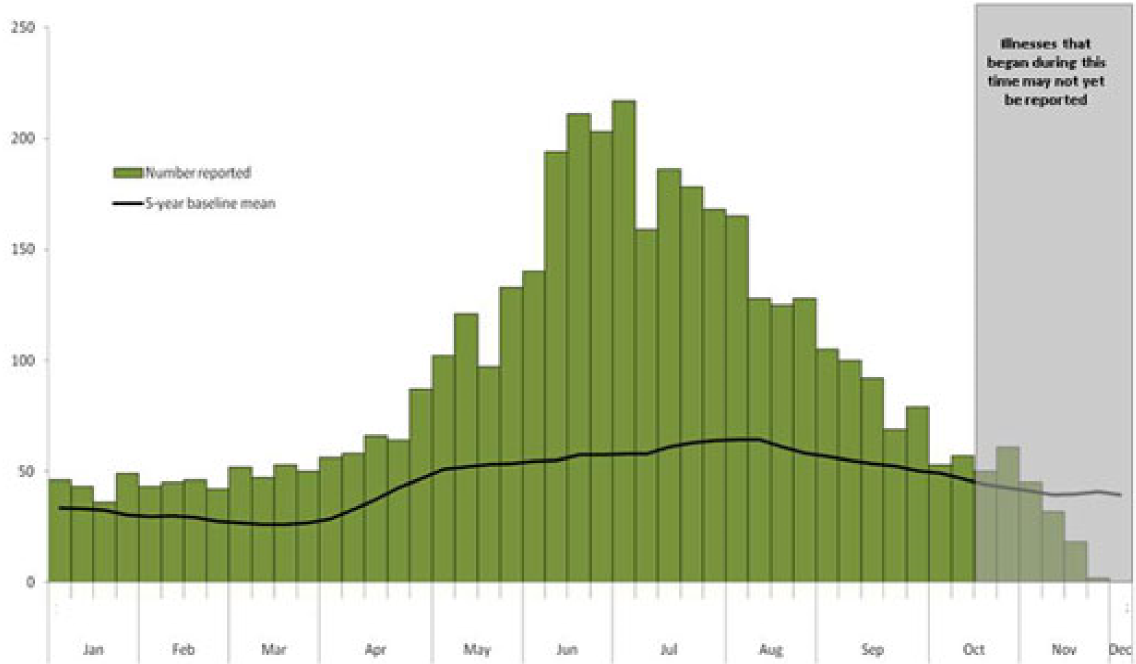
Third, we test the sensitivity of the baseline results to using only one month after the event week. Columns (5) - (8) in table 3.8 test the sensitivity to the time lag after the event. We obtain data on a second post-event month and include a total of 8 weeks after the event week for all years. Results are somewhat larger but similar in magnitude: an 11 to 13 percent drop for the first post-event month versus an original 8 to 10 percent drop. Once a second post-event month is included, the overall shell eggs category and the traditional shell eggs class show similar but slightly lower drops. The Value Added Specialty Eggs show a larger drop of 27 percent but represent only 13 percent of sales in our sample. The results for the Large Traditional Shell Eggs subclass are similar but somewhat larger than the ones for the first pre-event month in tables 3.8 and 3.3. Overall, the results for the second post-event month show similar findings, suggesting that the effect lasted more than one month.

3.6 Conclusion

Using data from a large scanner data set that has detailed purchasing records from over 600 stores from a national grocery chain, this paper studies how consumer purchases reacted after two Iowa farms found Salmonella in their eggs and started the largest egg recall in the United States. Infected eggs were recalled through codes clearly labeled on egg boxes so that, after the recall, there were no infected eggs in stores. By comparing purchases in a "treated" state, California, and a "control" state, Washington, we test whether consumers reduced egg purchases despite the thoroughness of the recall. We find a statistically significant and robust decrease of around 9 percent in egg purchases following the event. Given an overall price elasticity of demand for eggs in U.S. households of -0.1, this sales reduction is comparable to an almost 100% increase in prices. The analysis shows that, on average, consumers decreased their overall egg purchases, rather than substituting other type of eggs that may be perceived as having a lower probability of Salmonella. Further, while stores located in zip codes with higher mean income did not exhibit additional reductions in sales, zip codes with a higher mean household size did. We also exploit the fact that, due to its distribution chain, only stores in the national grocery chain's Northern California division had infected eggs while stores in the Southern California division did not. We find that stores in Southern California experienced decreased overall egg purchases as well. The drop in Southern California is half the magnitude of the drop in Northern California stores, suggesting the role of media coverage and updating of beliefs.

Consistent with previous literature on the effects of food borne disease outbreaks and government warnings, our results show that consumers do respond, at least temporarily, to outbreaks. Resulting lower purchases have policy implications for consumers, producers and policy makers and contribute to the discussion on additional investments in health safety and enforcement of existing regulation.

Figure 3.1: Epidemic Curve: Enteriditis Infections Matching PFGE Pattern

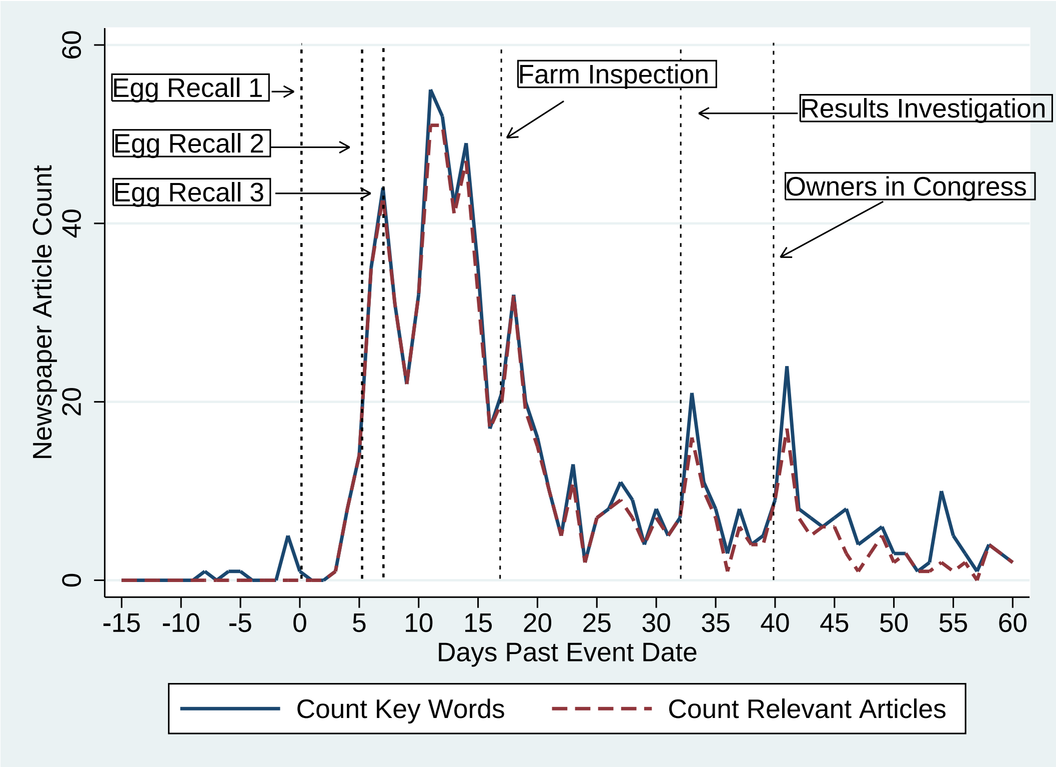


Source: CDC (last modified December 2010). Notes (from CDC): This figure shows an epidemic curve for Enteriditis infections matching PFGE (Pulsed-Field Gel Electrophoresis) patterns. PFGE patterns are used to identify bacteria. From May 1 to November 30, 2010, a total of 3,578 illnesses were reported. However, some cases from this period may not have been reported at that time, and some of these cases may not be related to the 2010 Salmonella egg outbreak. Based on the previous 5 years of reports, we would expect approximately 1,639 total illnesses to occur during this same period. This means there are approximately 1,939 reported illnesses that are likely to be associated with this outbreak. Because of the large number of expected cases during this period, standard methods of molecular subtyping alone are not sufficient to determine which reported cases might be outbreak-associated. Human Salmonella Enteritidis infections that occurred after October 28, 2010 might not yet have been reported due to the time it takes between when a person becomes ill and when the illness is reported. This typically takes two to three weeks for Salmonella, but can take up to six weeks.

Figure 3.2: Identifying Infected Eggs

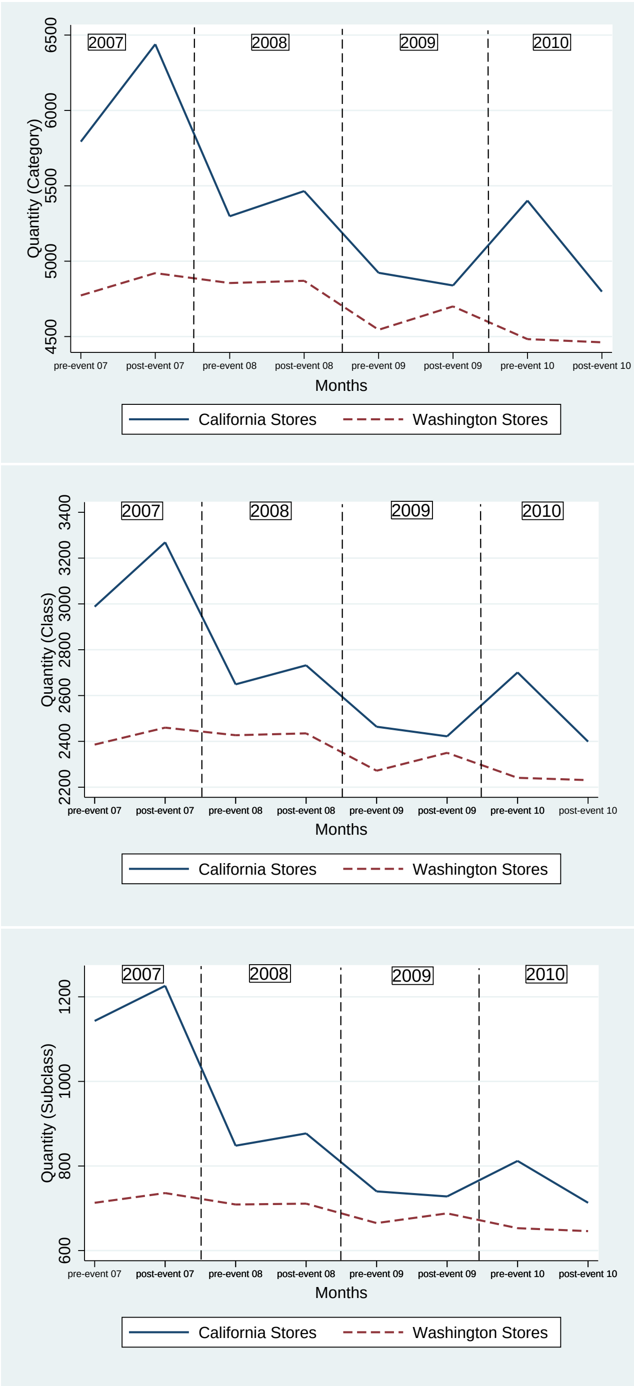
Source (picture): http://whatscookingamerica.net/Eggs/EggCartonCode.jpg. Notes: Egg cartons with the USDA grade shield on them must display the "pack date" (the day that the eggs were washed, graded, and placed in the carton). The number is a three-digit code that represents the consecutive day of the year (the "Julian Date") starting with January 1 as 001 and ending with December 31 as 365. The "sell-by" date appearing on a carton bearing the USDA grade shield may not exceed 45 days from the pack date (USDA). Plants that are not under USDA inspection are governed by the state laws where the eggs are packed and/or sold. Most states require a pack date.

Figure 3.3: Newspaper Coverage



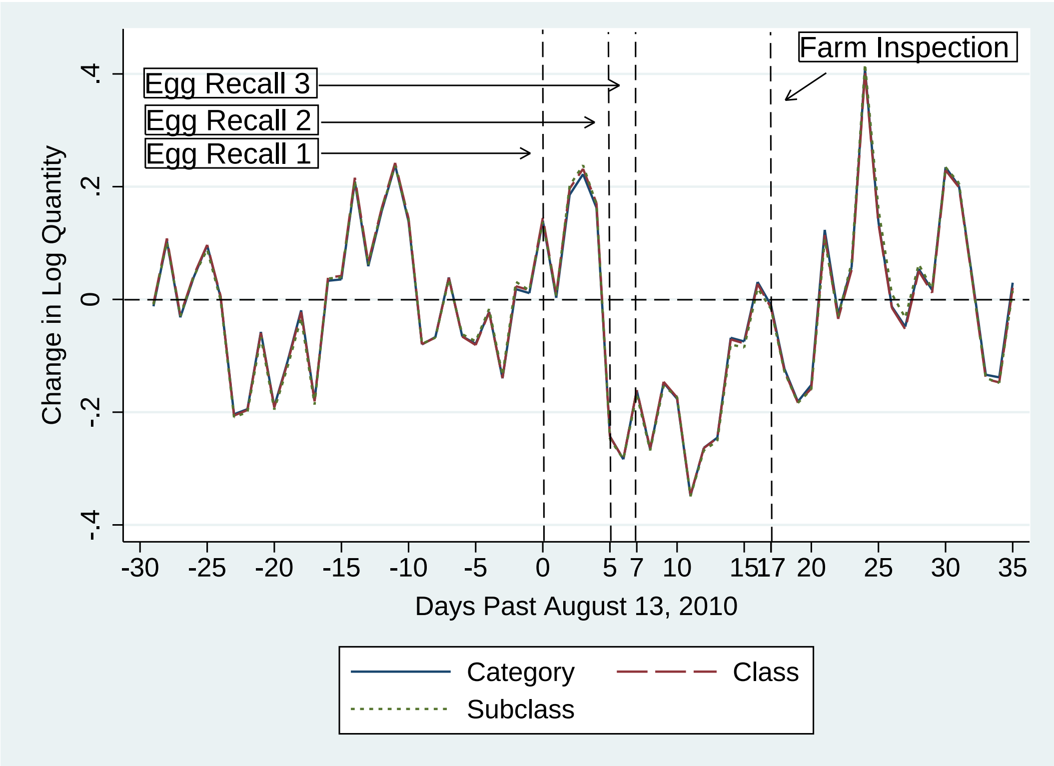
Notes: This figure displays the result of a Lexis-Nexis search that counts the number of articles in major newspapers in the U.S. that include the words “Salmonella” and “Eggs” on a given day. The solid line plots the daily article count with the words “Salmonella” and “Eggs,” while the dashed line plots the daily article count with the words “Salmonella” and “Eggs;” we checked these articles to verify that they were relevant to the 2010 Salmonella Egg Outbreak. Dashed vertical lines indicate major events linked to the outbreak, in particular the three egg recalls (the “event week”), the USDA farm inspection, the results of investigations and the day when the owners of the two Iowa farms appeared before Congress.

Figure 3.4: Evolution of Average Monthly Sales by Month and State by Aggregation Level



Notes: The top figure shows the evolution of average monthly sales by month and state when quantities of egg boxes sold are aggregated at the category level (shell eggs). The middle figure shows the evolution of average monthly sales by month and state when quantities of egg boxes sold are aggregated at the class level (traditional shell eggs and value added specialty eggs). The bottom figure shows the evolution of average monthly sales by month and state when quantities of egg boxes sold are aggregated at the subclass level (large, extra large, jumbo, brown, organic, cage free and nutrient enhanced eggs). Months denotes one pre-event month and one post-event month for each year (2007, 2008, 2009 and 2010). Months are not continuous in time.

Figure 3.5: Abnormal Daily Changes in Egg Purchases Following the Egg Recalls



Notes: Figure plots changes in log egg purchases (in quantities of egg boxes sold) under category, class and subclass aggregations for stores in California only. Day 0 is August 13, 2010, when the first egg recall took place. Abnormal changes are net of price, store-by-aggregation fixed effects and weekday fixed effects.

Table 3.1: Descriptive Statistics

Panel A: Scanner Data Set from Supermarket Chain					
Raw Data Set (N=22,657,391)					
	Obs	Mean	Std. Dev.	Min	Max
Year	4	2008.5	1.10	2007	2010
Month	3	8.04	0.77	7	9
Day	31	15.57	9.28	1	31
Store ID	654	1700.22	818.63	91	4616
Aggregation at the Category Level					
Log Quantity	5,232	8.36	0.55	4.49	11.60
Log Price	5,232	1.23	0.26	0.51	2.61
Aggregation at the Class Level					
Log Quantity	10,417	7.05	1.48	0	11.60
Log Price	10,417	1.28	0.24	0.51	2.61
Aggregation at the Subclass Level					
Log Quantity	33,164	5.27	1.60	0	11.59
Log Price	33,164	1.35	0.30	0.39	2.71

Panel B: Socio-Economic Data For Zip-Code of Supermarket					
	Obs	Mean	Std. Dev.	Min	Max
Income (10,000 USD)	637	5.510	1.923	2.007	14.542
Household Size	637	2.62	0.41	1.41	5.03

Notes: Quantities are in egg boxes and prices are in USD. Panel A displays descriptive statistics for the scanner data set. Data are presented for the raw data set and at the different aggregation levels (category, class and subclass). Time and store variables show the number of unique observations. Panel B displays socio-economic characteristics (income in 10,000 USD and household size from the 2000 U.S. Census) of the zip code in which the stores are located.

Table 3.2: Abnormal Monthly Changes for Egg Purchases Following Egg Recalls

	(1)	(2)	(3)
	Log Q	Log Q	Log Q
Event	-0.0475***	-0.0570***	0.0448**
	(0.00971)	(0.0105)	(0.0190)
Log Price	-0.00564	-0.00738	-0.154
	(0.0100)	(0.0104)	(0.135)
Event * CA	-0.0873**	-0.0949**	-0.103*
	(0.0378)	(0.0394)	(0.0542)
Constant	8.373***	8.269***	5.983***
	(0.0134)	(0.0140)	(0.172)
Aggregation	Category	Class	Class
Agg. Type	Shell Eggs	Traditional	Specialty
Observations	5,232	5,232	5,185
R-squared	0.915	0.909	0.979

Notes: Table tests for abnormal monthly changes in egg purchases following the three egg recalls. Column (1) aggregates sales at the category level (shell eggs). Column (2) aggregates sales at the class level "Traditional Shell Eggs" and column (3) aggregates sales at the class level "Value Added Specialty Eggs." Log price is the log of the average price of the corresponding aggregation level. All regressions include month-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the division by month level.

Table 3.3: Abnormal Monthly Changes for Egg Purchases Following Egg Recalls by Subclass

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q
Event	-0.0652***	0.198***	-0.0719*	0.114	0.0243	-0.0203	0.238***
	(0.0115)	(0.0198)	(0.0357)	(0.111)	(0.0594)	(0.0606)	(0.0850)
Log Price Subclass	-0.00797	-0.376***	-0.0197	-1.657**	0.0579	-4.751**	-3.015***
	(0.00694)	(0.104)	(0.205)	(0.795)	(0.0387)	(2.277)	(0.585)
Event * CA	-0.105**	0.0471	-0.0491	-0.0963	0.00857	-0.255	-0.0775
	(0.0409)	(0.0358)	(0.0497)	(0.187)	(0.0747)	(0.203)	(0.114)
Constant	8.146***	5.781***	5.010***	6.788***	4.982***	10.82***	7.567***
	(0.0114)	(0.134)	(0.250)	(0.970)	(0.0612)	(3.123)	(0.760)
Observations	5,232	5,163	5,036	4,059	4,480	4,818	4,376
R-squared	0.915	0.969	0.946	0.941	0.988	0.939	0.919
Aggregation	Subclass	Subclass	Subclass	Subclass	Subclass	Subclass	Subclass
Class	Traditional	Traditional	Traditional	Specialty	Specialty	Specialty	Specialty
Subclass	Large	Extra Large	Jumbo	Brown	Organic	Cage Free	Nutrient
Market Share (2009)	79%	3%	4%	3%	6%	3%	1%

Notes: Table tests for abnormal monthly changes of egg purchases by subclass. Log Price Subclass is the log of the average price of the corresponding subclass level. All regressions include month-by-year fixed effects and well as month fixed effects to account for seasonal purchasing patterns. Market share is the average market share of sales of shell eggs in the sample in the year 2009. Robust standard errors are in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the division by month level.

Table 3.4: Price Response and Abnormal Monthly Changes Without Price

	(1) Log P	(2) Log P	(3) Log P	(4) Log P	(5) Log Q	(6) Log Q	(7) Log Q	(8) Log Q
Event	0.0393*	0.0393*	0.0859***	0.0507	-0.0478***	-0.0573***	0.0316***	-0.0656***
	(0.0231)	(0.0231)	(0.0260)	(0.0350)	(0.00958)	(0.0103)	(0.00919)	(0.0115)
Event * CA	0.0536	0.0536	-0.0231	0.119***	-0.0876**	-0.0953**	-0.0995*	-0.106**
	(0.0352)	(0.0352)	(0.0328)	(0.0412)	(0.0379)	(0.0396)	(0.0525)	(0.0409)
Constant	1.207***	1.207***	1.320***	1.423***	8.366***	8.260***	5.780***	8.134***
	(0.00594)	(0.00595)	(0.00678)	(0.00824)	(0.00742)	(0.00779)	(0.0196)	(0.00766)
Aggregation	Category	Class	Class	Subclass	Category	Class	Class	Subclass
Agg. Type	Shell Eggs	Traditional	Specialty	Large	Shell Eggs	Traditional	Specialty	Large
Observations	5,232	5,232	5,185	5,232	5,232	5,232	5,185	5,232
R-squared	0.844	0.844	0.902	0.821	0.915	0.909	0.979	0.915

Notes: Columns (1) - (4) test whether stores adjusted prices in response to the egg recalls and have the log of price as the dependent variable. Columns (5) - (8) report the abnormal monthly changes for egg purchases following the egg recalls without controlling for price and have the log of quantity as the dependent variable. All regressions include month-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. The “Category” aggregation level includes one category (shell eggs); the “Class” aggregation level has two separate classes (traditional shell eggs and value added specialty eggs); and the “Subclass” aggregation level presented in this table only includes Large Traditional Shell Eggs. Log price is the log of the average price of the corresponding aggregation level. Robust standard errors are in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the division by month level.

Table 3.5: Abnormal Monthly Changes for Egg Purchases Following Egg Recalls by Demographics

	(1)	(2)	(3)
	Log Q	Log Q	Log Q
Event	-0.0461***	-0.0556***	-0.0658***
	(0.00831)	(0.00864)	(0.00977)
Log Price	-0.00338	-0.00419	-0.00691
	(0.0103)	(0.0106)	(0.00657)
Event * CA	-0.0899**	-0.0972**	-0.104**
	(0.0378)	(0.0386)	(0.0394)
Event * Inc	-0.0151***	-0.0157***	-0.0184***
	(0.00282)	(0.00276)	(0.00282)
Event * CA * Inc	0.0106	0.0103	0.0101
	(0.00707)	(0.00725)	(0.00774)
Event * HH Size	0.204***	0.207***	0.213***
	(0.0148)	(0.0142)	(0.0145)
Event * CA * HH Size	-0.193***	-0.192***	-0.195***
	(0.0311)	(0.0320)	(0.0324)
Constant	8.363***	8.258***	8.137***
	(0.0146)	(0.0149)	(0.0110)
Aggregation	Category	Class-Traditional	Subclass-Large
Observations	5,096	5,096	5,096
R-squared	0.915	0.910	0.916

Notes: Table tests for heterogeneous effects by socio-economic groups. The “Category” aggregation level includes one category (shell eggs); the “Class” aggregation level includes Traditional Shell Eggs only; and the “Subclass” aggregation level includes Large Traditional Shell Eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include aggregation month-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Income is the demeaned average income in the zip code in which the store is located (in 10,000 USD) and HH Size is the demeaned average household size in the zip code in which the store is located. Robust standard errors are in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the division by month level.

Table 3.6: Abnormal Monthly Changes for Egg Purchases Following Egg Recalls by Californian Geographical Divisions

	(1)	(2)	(3)
	Log Q	Log Q	Log Q
Event	-0.0478***	-0.0573***	-0.0652***
	(0.00961)	(0.0104)	(0.0115)
Log Price	0.00222	0.000528	-0.00742
	(0.00869)	(0.00885)	(0.00706)
Event* Northern CA	-0.125***	-0.137***	-0.151***
	(0.0226)	(0.0250)	(0.0247)
Event * Southern CA	-0.0534**	-0.0568**	-0.0621***
	(0.0211)	(0.0222)	(0.0219)
Constant	8.363***	8.259***	8.145***
	(0.0101)	(0.0107)	(0.0105)
Aggregation	Category	Class-Traditional	Subclass-Large
Observations	5,232	5,232	5,232
R-squared	0.915	0.909	0.916

Notes: Table tests for heterogeneous effects by geographic divisions (only Northern California stores had infected eggs). The “Category” aggregation level includes one category (shell eggs); the “Class” aggregation level includes Traditional Shell Eggs only; and the “Subclass” aggregation level includes Large Traditional Shell Eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include month-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the division by month level.

Table 3.7: Sensitivity of Abnormal Changes in Log Egg Purchases to Assumptions about Seasonality Estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q
Event	-0.0240***	-0.0378***	0.103***	-0.0463***	-0.0429***	-0.0583***	-0.0415***
	(0.00606)	(0.00662)	(0.00623)	(0.00668)	(0.0112)	(0.00640)	(0.0126)
Log P	0.000575	-0.00360	0.0219	-0.000599	-0.000489	-0.00790	-0.00851
	(0.00739)	(0.00900)	(0.0576)	(0.00473)	(0.00602)	(0.0116)	(0.0116)
Event * CA	-0.0824**	-0.0941**	-0.0255	-0.107**	-0.0736*	-0.0738*	-0.115***
	(0.0346)	(0.0359)	(0.0155)	(0.0377)	(0.0380)	(0.0406)	(0.0372)
Constant	8.424***	8.294***	6.172***	8.202***	8.441***	8.340***	8.366***
	(0.0121)	(0.0136)	(0.0762)	(0.0113)	(0.0102)	(0.0153)	(0.0152)
Aggregation	Category	Class	Class	Subclass	Category	Category	Category
Agg. Type	Shell Eggs	Traditional	Specialty	Large	Shell Eggs	Shell Eggs	Shell Eggs
Excluded Years	2007-2008	2007-2008	2007-2008	2007-2008	2007	2008	2009
Observations	2,616	2,616	2,614	2,616	3,924	3,924	3,924
R-squared	0.974	0.973	0.984	0.975	0.979	0.901	0.903

Notes: Table tests for sensitivity of abnormal monthly changes in egg purchases to assumptions about the seasonality estimates. Columns (1) - (4) include only one pre-event year and exclude data for the years 2007 and 2008. Columns (5) - (8) exclude data from each of the pre-event years. The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level includes two classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level includes Large Traditional Shell Eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include month-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the division by month level.

Table 3.8: Sensitivity of Abnormal Changes in Log Egg Purchases to the Control State and Months After the Event

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q	Log Q
Event M1	-0.100***	-0.113***	-0.0941***	-0.127***	-0.0220**	-0.0317***	0.0777***	-0.0406***
	(0.0263)	(0.0267)	(0.0245)	(0.0275)	(0.0105)	(0.0105)	(0.0258)	(0.0120)
Event M2					-0.0337**	-0.0376**	0.00108	-0.0409**
					(0.0147)	(0.0143)	(0.0282)	(0.0164)
Log P	-0.00949	-0.0139	-0.331***	-0.0114	-0.0103	-0.0118	-0.223**	-0.00747
	(0.0601)	(0.0612)	(0.0705)	(0.0170)	(0.00980)	(0.00957)	(0.110)	(0.00773)
Event M1*North CA	-0.0709*	-0.0794**	0.0948***	-0.0891**				
	(0.0376)	(0.0383)	(0.0350)	(0.0395)				
Event M1 * CA					-0.112***	-0.119***	-0.131*	-0.129***
					(0.0349)	(0.0359)	(0.0693)	(0.0376)
Event M2 * CA					-0.110***	-0.106***	-0.269***	-0.135***
					(0.0309)	(0.0322)	(0.0961)	(0.0322)
Constant	8.373***	8.267***	6.238***	8.145***	8.378***	8.274***	6.068***	8.145***
	(0.0759)	(0.0773)	(0.0989)	(0.0271)	(0.0173)	(0.0173)	(0.133)	(0.0142)
Aggregation	Category	Class	Class	Subclass	Category	Class	Class	Subclass
Agg. Type	Shell Eggs	Traditional	Specialty	Large	Shell Eggs	Traditional	Specialty	Large
Observations	3,920	3,920	3,873	3,920	7,824	7,824	7,763	7,824
R-squared	0.910	0.904	0.981	0.911	0.886	0.878	0.968	0.887

Notes: Table tests for sensitivity of results to the control state and the time period after the event week (August 13 to August 20, 2010). Columns (1) - (4) use Southern California as a control "state" instead of Washington. Column (5) - (8) include a second post-event month. The 4 week period after the event week is labeled "Event M1" and the following 4 week period is labeled "Event M2". The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level includes two classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level includes Large Traditional Shell Eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include month-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the division by month level.

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Appendix A

Laboratory Experiment With UC Berkeley Students and Staff

This appendix describes another experiment I designed and conducted at UC Berkeley during May and June 2012. In total, 209 UC Berkeley students or staff participated in a laboratory experiment in seven different sessions. The experiment was entirely computer-based and, as in the Brazilian experiment, consisted of price and environmental persuasion communication randomizations. The proposed prices for the LED were \$0, \$2 and \$4.

A.1 Descriptive Statistics, Comparison of Means and Identification Strategy

Table A.1 summarizes responses to the survey. Sixty six percent of participants are female, they are on average 21 years old and college juniors. Thirty percent of them are "poor" (defined as being in the 25th percentile of participants' income), 64% of them have at least one EELB at home and 21% of them do not know what type of light bulb they have at home.[1] Only 27% of subjects fully pay for the electricity they consume, while 42% of them partially pay. Most participants consider environmental problems such as global warming important: 85% of participants consider them "important," "very important" or "extremely important." Nearly half of the participants received the environmental persuasion communication and LED take-up is on average 54%.

To assess covariate balance, I compare means of the overall reference group (experimental group 1) with means of the other groups. I estimate the following regression for each variable used in the estimation:

$$X_{is} = \alpha + \beta Price2_{is} + \gamma Price4_{is} + \lambda EPC_{is} + \eta_s + \varepsilon_{is} \tag{A.1}$$

where X_{is} is a set of individual characteristics, $Price2_{is}$ is an indicator variable for whether individual i from session s was offered the LED at \$2, $Price4_{is}$ is an indicator variable for whether i was offered the LED at \$4, λEPC_{is} is an indicator variable for whether i received the environmental persuasion communication, η_s includes session fixed effects and ϵ_{is} is a random error term. Table A.2 shows the results. In most cases, means are not statistically different across groups. Only one variable had statistically different means across groups. On average, participants who received the environmental persuasion communication had more EELBs than those in the reference group (significant at the 10% level).[2]

The analysis of this experiment uses the following linear probability model or logit regression:

$$Takeup_{is} = \alpha + \beta EPC_{is} + \gamma_{pis} + \lambda X_{is} + \eta_s + \varepsilon_{is} \tag{A.2}$$

[1] This is probably due to the fact that they may not be responsible for light bulb purchases in their homes. Many students live in shared housing (dorms, shared apartments or houses) and thus may not be aware about the type of light bulbs they have at home.

[2] Assuming linearity, I control for this variable in order to deal with the difference in means across groups.

where $Takeup_{is}$ equals unity if individual i in session s chooses the LED and 0 if she chooses the ILB, EPC_{is} is an indicator variable that equals unity if individual i received the environmental persuasive communication and 0 otherwise, γ_{pis} are indicator variables for each price group ($0, $2 or $4) and equal unity if i was offered the LED at that price and 0 otherwise, X_{is} includes relevant controls that might affect LED adoption (gender, age, years of schooling, poverty status, whether the individual has an EELB at home, whether she fully or partially pays for the electricity consumed and the importance of environmental problems such as global warming), η_s includes session fixed effects and ε_{is} is a random error term. Results are estimated using both a linear probability model and a logit regression.

A.2 Average Effects

Table A.3 shows the overall effect of the environmental persuasion communication on LED take-up using both a linear probability model (columns 1, 3 and 5) and a logit regression (columns 2, 4 and 6). Columns (1) and (2) suggest that the overall effect of the environmental persuasion communication on the probability of LED take-up is around 9 percentage points without any price or demographic controls and under both models. Once price controls are included, columns (3) and (4) suggest that the probability of LED take-up is around 7 percentage points with both the LPM and the logit regression. Columns (5) and (6) suggest that, once demographic controls are added, the probability is still around 7 percentage points, although slightly higher. However, none of these results are significant. The effect of an increase in price is large and significant at the 1% level: column (5) shows that under the LPM, once price and demographic controls are included, the probability of picking the LED over the ILB decreases by around 47 percentage points when price increases from $0 to $2 and decreases by 64 percentage points when price increases from $0 to $4. Age has a negative effect on the probability of LED take-up but this result should be interpreted with caution because there is not much variation in age in this population. Not knowing what type of light bulb they have at home decreases participants' probability of LED take-up by around 23 percentage points (significant at the 5% level) and considering environmental problems such as global warming at least "important" increases the probability of LED take-up by around 19 percentage points (significant at the 5% level under both the LPM and logit regression).

A.3 Estimation Results by Price

Figure A.1 shows the share of LED take-up by price and by whether subjects received the environmental persuasion communication (solid line) or not (dashed line).[3] The figure

[3]This figure shows the means of each experimental group, two per price level, with a line connecting the means by whether individuals received the environmental persuasion communication or not. The

shows that, at \$0, take-up is almost perfect and there is no room for the environmental persuasion communication to have an effect. At \$2, there seems to be no effect of the environmental persuasion communication. At a price of \$4 and without any controls, the environmental persuasion communication increases LED take-up by around 20 percentage points.

At a price of \$2, the average take-up of LEDs is 55% and at the price of \$4, the average take up is 37.5%. Therefore, the price elasticity of demand of increasing the LED price from \$2 to \$4 is [(0.375-0.55)/0.55]/[(4-2)/2] =-0.31, showing that LEDs are a relatively inelastic good over this price range and for this population. Given the results observed in figure A.1, I estimate the effect of the environmental persuasion communication at the price of \$4 under an LPM and a logit regression. Table A.4 shows the results using data only from participants that were offered the LED at \$4. Columns (1) and (3) show results from an LPM and columns (2) and (4) show results for a logit regression. Columns (1) and (2) suggest that, at a price of \$4, the environmental persuasion communication increases the probability of LED take-up by around 16 percentage points. The result is not significant under the LPM but it is significant, at the 10% level, under the logit regression. Columns (3) and (4) suggest that once demographic controls are included, the environmental persuasion communication increases the probability of LED take-up at \$4 by around 14 percentage points but the results are not significant. None of the demographic controls are significant in this specification.

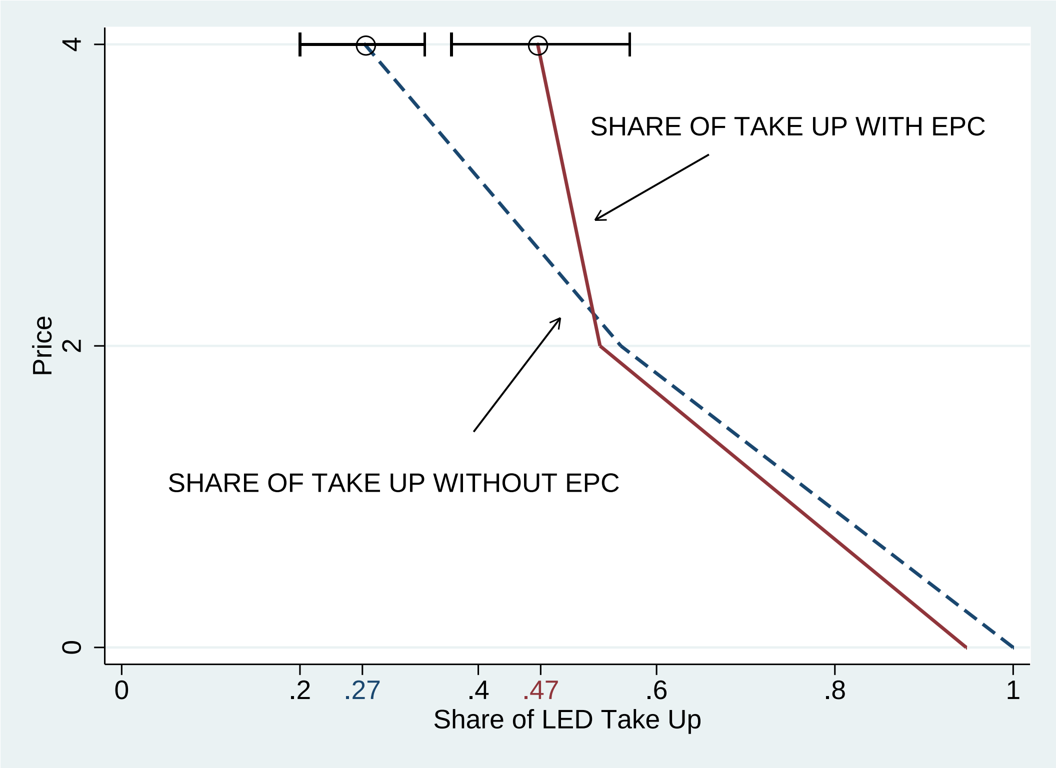
Table A.5 shows the effect of the environmental persuasion communication at \$4 using the full dataset and interactions. Columns (1) and (3) show results from a LPM and columns (2) and (4) show results for a logit regression.[4] Columns (1) and (2) show that at \$4 and without demographic controls, the environmental persuasion communication increases take-up by 19.2 percentage points under the LPM and by 16.9 percentage points with the logit regression. With demographic controls, the environmental persuasion communication increases take-up at \$4 by 18.3 percentage points with the LPM and by 15.7 percentage points with the logit regression. All of these results are significant at the 10% level. The effect of the environmental persuasive communication on LED take-up at \$2 is around 1 percentage point and not significant.

I also test for heterogeneous effects with an LPM and a logit regression. As in the Brazilian experiment, I find that the environmental persuasion communication has a differentiated effect by income level and by environmental preferences, but due to the small sample size the results are not significant (not shown).

confidence intervals are from the corresponding regressions without controls.

[4]Due to the small sample size and many cuts in the data, the logit regression shows large coefficients and standard errors for the effects of the EPC and price alone as well as for the double interactions. However, the overall effects of the EPC at \$2 and \$4 are relatively similar to the ones from the LPM.

Figure A.1: Share of LED Take UP by Price and Environmental Persuasion Communication (UC Berkeley Experiment)



Notes: This graph shows the share of LEDs picked over ILBs by price levels and by whether participants received the environmental persuasion communication (solid line) or not (dashed line). Price levels are \$0, \$2 and \$4. Lines connect means by price groups and by EPC. Confidence intervals are from the corresponding regressions without controls.

Table A.1: Summary Statistics (UC Berkeley Experiment)

	Obs	Mean	Std. Dev	Min	Max
PANEL A: INDIVIDUAL CHARACTERISTICS					
Female	209	0.665	0.473	0	1
Age	209	21.229	3.137	18	45
Yrs Schooling	209	14.779	1.602	12	21
Poor	209	0.301	0.459	0	1
PANEL B: TYPE OF LIGHT BULB AT HOME AND TYPE OF ELECTRICITY PAYMENT					
EELB	209	0.641	0.480	0	1
Doesn't Know LB	209	0.210	0.408	0	1
Fully Pays	209	0.272	0.446	0	1
Partially Pays	209	0.421	0.494	0	1
PANEL C: ENVIRONMENTAL PREFERENCES					
Imp. Env Pbls	209	0.851	0.356	0	1
PANEL D: TREATMENT AND OUTCOME VARIABLES					
EPC	209	0.492	0.501	0	1
LED Take-Up	209	0.540	0.499	0	1
No. of Individuals: 209					
No. of Sessions: 7					

Notes: Participants were UC Berkeley adult students and staff. Female equals 1 if the participant is a female and 0 if he is a male, Age is the demeaned age of the participant and Yrs Schooling is the demeaned years of schooling of the participant. Poor is equal to 1 if the participant is in the 25th percentile of participants' income ($700 or less). EELB is a dummy for whether the participant has at least one energy efficient light bulb at home (CFL or LED). Doesn't Know LB is an indicator variable for whether the participant does not know what type of light bulb she has at home. Fully Pays is an indicator variable for whether the participant fully pays for the electricity she consumes (as opposed to partially paying or not paying at all) and Partially Pays is an indicator variable for whether the participant partially pays for the electricity she consumes (as opposed to fully paying or not paying at all). Imp. Env Pbls is a self-assessed measure of how important environmental problems such as global warming are to the participant, it is an indicator variable equal to one for environmental problems being "important", "very important" or "extremely important". EPC is a dummy for whether the participant received the environmental persuasion communication and LED Take- Up is an indicator variable for whether the participant chose the LED over the ILB.

Table A.2: Comparison of Means Between Reference and Treatment Groups (UC Berkeley Experiment)

	Sample Mean	Ref. Group Mean (P=$0, no ET)	P= $2 T-C	P= $4 T-C	EPC T-C
Female	0.665	0.769	-0.033	-0.099	0.070
	(0.473)	(0.438)	(0.100)	(0.098)	(0.065)
Age	21.229	22.538	-0.891	-0.956	0.257
	(3.137)	(3.281)	(0.763)	(0.772)	(0.465)
Yrs Schooling	14.779	15.615	-0.314	-0.447	-0.031
	(1.602)	(2.063)	(0.376)	(0.377)	(0.231)
Poor	0.301	0.461	-0.145	-0.089	0.021
	(0.459)	(0.518)	(0.101)	(0.102)	(0.065)
EELB	0.641	0.538	0.089	0.030	0.122*
	(0.480)	(0.518)	(0.106)	(0.105)	(0.067)
Doesn't Know LB	0.210	0.384	-0.152	-0.087	-0.081
	(0.408)	(0.506)	(0.096)	(0.098)	(0.057)
Fully Pays	0.272	0.307	0.031	-0.044	-0.002
	(0.446)	(0.480)	(0.104)	(0.099)	(0.062)
Partially Pays	0.421	0.461	-0.056	-0.010	0.013
	(0.494)	(0.518)	(0.112)	(0.110)	(0.069)
Imp. Env Pbls	0.851	0.923	-0.082	0.015	-0.034
	(0.356)	(0.277)	(0.074)	(0.071)	(0.049)
F test p-value			1.01	0.83	1.03
Observations	209	13	89	88	103

Notes: The first and second columns show the means of individual characteristics in the overall sample and reference group (price=$0, no EPC) respectively, with standard deviations in parentheses. The third, fourth and fifth columns present differences in means between the specified treatment group and the reference group, with standard deviations in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Female equals 1 if the participant is a female and 0 if he is a male, Age is the demeaned age of the participant and Yrs Schooling is the demeaned years of schooling of the participant. Poor is equal to 1 if the participant is in the 25th percentile of participants' income ($700 or less). EELB is a dummy for whether the participant has at least one energy efficient light bulb at home (CFL or LED). Doesn't Know LB is an indicator variable for whether the participant does not know what type of light bulb she has at home. Fully Pays is an indicator variable for whether the participant fully pays for the electricity she consumes (as opposed to partially paying or not paying at all) and Partially Pays is an indicator variable for whether the participant partially pays for the electricity she consumes (as opposed to fully paying or not paying at all). Imp. Env Pbls is a self-assessed measure of how important environmental problems such as global warming are to the participant, it is an indicator variable equal to one for environmental problems being "important", "very important" or "extremely important" (as opposed to "not important" or less). All regressions include session fixed effects.

Table A.3: Probability of Picking the LED as a Function of the EPC, Price and Covariates

	LED Take Up (1=yes, 0= no)					
	LPM	Logit	LPM	Logit	LPM	Logit
	(1)	(2)	(3)	(4)	(5)	(6)
EPC	0.0925	0.0918	0.0702	0.0669	0.0713	0.0794
	(0.0699)	(0.0672)	(0.0645)	(0.0621)	(0.0635)	(0.0596)
Price 2			-0.433***	-0.424***	-0.471***	-0.448***
			(0.0719)	(0.0623)	(0.0740)	(0.0533)
Price 4			-0.601***	-0.592***	-0.644***	-0.609***
			(0.0677)	(0.0599)	(0.0647)	(0.0517)
Female					0.0489	0.0485
					(0.0699)	(0.0633)
Age					-0.0299***	-0.0554***
					(0.00907)	(0.0201)
Yrs Schooling					-0.0102	0.0138
					(0.0216)	(0.0289)
Poor					-0.00745	-0.0147
					(0.0737)	(0.0716)
EELB					-0.0813	-0.0873
					(0.0849)	(0.0784)
Doesn't Know LB					-0.224**	-0.236**
					(0.103)	(0.0948)
Fully Pays					0.112	0.111
					(0.0849)	(0.0826)
Partially Pays					0.112	0.107
					(0.0779)	(0.0709)
Imp. Env Pbls					0.186**	0.205**
					(0.0812)	(0.0862)
Constant	0.560***		0.914***		0.774***	
	(0.0916)		(0.0654)		(0.144)	
Observations	209	209	209	209	209	209
R-squared	0.028	0.020	0.181	0.158	0.276	0.261

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Received the EPC is a dummy for whether the participant received the environmental persuasion communication, Price 2 (4) is a dummy for whether the participant was offered the LED at $2 ($4). The logit regression uses average marginal effects. All regressions include session fixed effects. Regression equation: $Takeup_{is} = \alpha + \beta EPC_{is} + \gamma_{pis} + \lambda X_{is} + \eta_s + \epsilon_{is}$.

Table A.4: Effect of the Environmental Persuasion Communication at a Price of $4

	LED Take Up (1=yes,0=no)			
	LPM	Logit	LPM	Logit
	(1)	(2)	(3)	(4)
EPC	0.160	0.155*	0.147	0.145
	(0.105)	(0.0932)	(0.121)	(0.0940)
Female			0.0160	0.0146
			(0.128)	(0.112)
Age			-0.0255	-0.0493
			(0.0178)	(0.0394)
Yrs Schooling			-0.00955	0.00552
			(0.0355)	(0.0504)
Poor			0.0532	0.0580
			(0.126)	(0.111)
EELB			-0.0465	-0.0461
			(0.151)	(0.139)
Doesn't Know LB			-0.202	-0.185
			(0.177)	(0.147)
Fully Pays			-0.00650	-0.0191
			(0.161)	(0.147)
Partially Pays			0.104	0.0917
			(0.134)	(0.119)
Imp. Env Pbls			0.0811	0.113
			(0.169)	(0.175)
Constant	0.277**		0.226	
	(0.130)		(0.243)	
Observations	88	88	88	88
R-squared	0.127	0.100	0.193	0.168

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. This table uses data from participants that were offered the LED at $4 only. The logit regression uses average marginal effects. All regressions include session fixed effects. Regression equation: $Takeup_{is} = \alpha + \beta EPC_{is} + \lambda X_{is} + \eta_s + \epsilon_{is}$.

Table A.5: Effect of the Environmental Persuasion Communication at a Price of $4 Using the Full Dataset

	LED Take Up (1=yes,0=no)			
	LPM	Logit	LPM	Logit
	(1)	(2)	(3)	(4)
EPC	-0.0405	-2.703	-0.0816	-2.427
	(0.0578)	(204.1)	(0.0736)	(223.2)
Price 2	-0.462***	-3.267	-0.538***	-3.160
	(0.0789)	(204.1)	(0.0982)	(223.2)
Price 4	-0.728***	-3.496	-0.793***	-3.363
	(0.0719)	(204.1)	(0.0926)	(223.2)
EPC * Price 2	0.0281	2.692	0.0935	2.446
	(0.124)	(204.1)	(0.128)	(223.2)
EPC * Price 4	0.233*	2.872	0.265**	2.585
	(0.120)	(204.1)	(0.129)	(223.2)
Female			0.0385	0.0359
			(0.0705)	(0.0637)
Age			-0.0299***	-0.0514***
			(0.00877)	(0.0194)
Yrs Schooling			-0.00912	0.0118
			(0.0221)	(0.0286)
Poor			-0.00904	-0.0186
			(0.0745)	(0.0710)
EELB			-0.0853	-0.0852
			(0.0846)	(0.0776)
Doesn't Know LB			-0.242**	-0.246***
			(0.104)	(0.0931)
Fully Pays			0.108	0.103
			(0.0837)	(0.0818)
Partially Pays			0.113	0.101
			(0.0783)	(0.0707)
Imp. Env Pbls			0.176**	0.199**
			(0.0818)	(0.0855)
Constant	0.984***		0.895***	
	(0.0585)		(0.159)	
EPC + EPC * Price 2	-0.012	-0.01	0.011	0.019
	(0.109)	(0.087)	(0.105)	(0.083)
EPC + EPC * Price 4	0.192*	0.169*	0.183*	0.157*
	(0.103)	(0.089)	(0.107)	(0.083)
Observations	209	209	209	209
R-squared	0.192	0.169	0.285	0.270

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. This table uses the full dataset with interactions. The logit regression uses average marginal effects. All regressions include session fixed effects. Regression equation: $Takeup_{is} = \alpha + \beta EPC_{is} + \gamma_{pis} + EPC_{is} * Price2_{is} + EPC_{is} * Price4_{is} + \lambda X_{is} + \eta_s + \epsilon_{is}$.