Essays in Environmental Economics

By

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Abstract

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Public initiative and referendum voting outcomes provide an opportune setting in which to study the demand for publicly provided goods and services, such as environmental quality and public education. In the first essay, I use census block group level voting outcomes on California statewide ballot propositions from 2006 to 2012 to test whether the relationship between voter support and income depends on a proposition's fiscal implications or the local availability of private substitutes. Support is modestly increasing in income when the proposition is associated with a regulatory change in the context of environmental protection. When propositions are tax or bond-funded, however, I find evidence of a convex or U-shaped relationship between median income and the share of votes in favor, consistent with the combined effects of a low tax burden on poor households and a low marginal utility of wealth among rich households. In the context of public education funding, I further find that the positive marginal effect of income at high income levels is moderated in block groups with greater availability of private substitutes, namely a greater density of nearby private schools.

Individuals can express their preferences for public goods, and environmental protection in particular, both as voters by supporting regulation or as consumers by choosing favorable alternatives, thus providing a unique opportunity to compare consumer and voter behavior within the same individual and regarding the same issue. In the second essay, I examine the relationship between willingness to pay a premium for products that avoid a controversial technology associated with environmental risks or externalities, with willingness to vote in favor of a ban or mandatory labeling of the technology. Based on a survey on genetically modified food, I find that the majority of respon-

dents make consumer and voter choices that can be explained by a standard utility maximization framework. However, certain respondent characteristics are correlated with inconsistent choice patterns. In particular, low-income voters appear to be overly supportive of regulation relative to their private willingness to pay. Voters who are uncertain about the safety of genetically modified food also tend to be more in favor of mandatory labeling than their consumer choices would imply.

While the first two essays consider the relationship between income and demand for environmental protection at a micro level, there are also much broader implications of this relationship. At the country level, higher GDP is often associated with stricter pollution regulation, which may imply a disproportionate amount of production of pollution-intensive goods in less wealthy countries. The hypothesis that countries with relatively strict pollution regulation will be more likely to import pollution intensive goods from countries with weaker or absent regulation is intuitively appealing and has found moderate support in a number of empirical studies. While these studies focus on the regulation of manufacturing industries, the underlying theoretical argument applies equally to the agricultural sector. The third essay assesses whether cross-country differences in pesticide regulation can induce such "pollution haven" effects. In particular, I estimate the impact of the international phaseout of methyl bromide on trade flows in agricultural products. I find robust evidence that cross-country differences in allowed methyl bromide usage affect trade flows, and show that the effect varies in magnitude and significance across commodities, largely in line with their baseline reliance on MeBr. The results do not suggest that countries granted exemptions from the phaseout for particular commodities, on the basis of such reliance, gained an unfair competitive advantage.

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1 Ballot Proposition Voting and the Demand for Publicly Provided Goods

1.1 Introduction

Public provision of goods and services, ranging from environmental quality to transportation infrastructure to public education, is one of the central roles of government. Understanding the general public's demand for these amenities is critical to determining the appropriate level of provision, and the level likely to be supported by the electorate. The study of demand for public goods is made difficult, however, by the absence of market data that reveals willingness to pay and its determinants. Public goods are instead the domain of legislation, and initiatives and referendums put to popular vote as ballot propositions are the most direct preference revealing mechanism. In this paper, I use proposition voting outcomes to characterize the relationship between demand for publicly provided goods, focusing on environmental protection and public education, and income. I show that the relationship depends on whether a proposition entails an increase in income taxes, and is further complicated by the availability of private substitutes.

Relative to alternative approaches to studying demand for public goods, most often environmental quality, the use of proposition voting outcomes offers several advantages. Voters decide on a single issue at a time by making a straightforward binary choice, so their votes are simple non-strategic indicators of their preferences. The issues are important and votes correspond to an actual and impactful outcome, so hypothetical bias is not a concern as it is with contingent valuation (Diamond and Hausman, 1994). Likewise voters are relatively informed about the issue, having been exposed to campaigning and given time to seek out additional information and formulate opinions, unlike in a survey setting (Ajzen et al., 1996). Use of voting outcomes also does not require any assumptions about the representativeness of a particular government, unlike studies that focus on actual public good expenditures (Bergstrom et al., 1982) or resulting outcomes such as pollution (McConnell, 1997).

In addition, more than seventy percent of the U.S. population now live in cities or states where they are able to vote directly on ballot propositions, and countries around the world continue to use referendums to decide critical issues (Lupia and Matsusaka, 2004, Matsusaka, 2005). In California, the archetypal example of direct democracy and the empirical setting for this paper, citizens have voted on over 350 propositions in the past century, many of which pertained to public provision of goods or services (Baldassare et al., 2013). Given the significance of the issue at stake in many ballot propositions, understanding how communities vote, and the relationship between voting outcomes and demographic and economic characteristics, is further important in its own right. Such insight can help predict which propositions are likely to find support and where, particularly as these characteristics evolve across communities over time.

In this paper, I estimate the relationship between income and voter support for statewide California propositions appearing on ballots between 2006 and 2012 regarding environmental protection and public education funding, as well as publicly provided goods more generally. Following the implications of an individual utility maximization framework aggregated up to the neighborhood level, I present evidence that the relationship differs between propositions with a fiscal implication, such as those that involve income tax increases or the issuance of bonds, and those that involve only a regulatory change. I test the hypothesis that proposition type matters in the context of environmental propositions, where there are examples of both fiscal and regulatory initiatives. I then provide evidence that the availability of private substitutes further affects the income-support relationship in the context of public education funding, where a clear and quantifiable private substitute is readily defined.

In light of the advantages of using ballot proposition voting data, a small literature has sought to analyze demand for environmental quality by way of initiative and referendum voting outcomes. Deacon and Shapiro (1975) first utilized this approach and laid out a theoretical foundation to justify the use of aggregate voting data to make inferences about individual preferences. They found that support for environmental regulation increases with income in the case of two particular propositions. Kahn and Matsusaka (1997) estimate the relationship between income and support for environmental ballot propositions in California at the county level, and conclude that the environment is generally a normal good but may be inferior at higher levels of income. More recently Wu and Cutter (2011) relate household income and support for environmental ballot measures using California voting data and find that areas with a relatively high percentage of middle income households are least supportive. Other studies find negative relationships between income and demand for environmental protection (Kahn, 2002, Kline, 2006).

This literature has loosely proposed, though not formalized or tested, two primary hypotheses to explain why support for environmental regulation is not monotonically increasing in income, despite the conventional and intuitive assumption that the environment is a normal good. First, given proportional or progressive taxation, it may be the case that wealthier households face a larger increase in their tax burden to fund increased provision of environmental quality (Kahn, 2002). Second, wealthier households may be more able to substitute with private goods, such as private open space and travel to cleaner locations (Kline, 2006, Kahn and Matsusaka, 1997). The role of private substitutes for publicly provided goods is addressed more rigorously by the theoretical literature regarding public education funding. Epple and Romano (1996), for example, show that wealthy households are more likely to choose private education and thus align with poor households to oppose middle income household demand for greater public education expenditures.

Although there are no direct empirical studies of income and actual voting outcomes regarding public education, a number of papers relate county or school district expenditures on public education to community characteristics. Much of this literature focuses on demographic characteristics and age in particular (Fletcher and Kenny, 2008). Fernandez and Rogerson (2001) estimate the effects of long-run income and find that income growth led to a one-to-one increase in public education spending in the US. In addition, a few studies have used survey data to more directly assess the determinants of individual demand for public education. Bergstrom et al. (1982) demonstrate a method to use such data to estimate income elasticities of demand. More recently, Brunner and Balsdon (2004) use survey data on intention to vote in favor of a statewide proposition and a hypothetical local proposition that pertain to education funding. As in the expenditure studies, they find evidence that age is negatively related to voter support, but the role of income is not considered explicitly.

I build on these existing strands of literature by first providing a unified conceptual framework regarding the relationship between income and voter support for public goods provision that explicitly accounts for both the differences between fiscal and regulatory propositions, and the role of private substitutes. I then test for the importance of these considerations using voting outcomes, demographic characteristics, and household income at a comparatively fine level of aggregation. The unit of observation for this study is a census block group, a subdivision of a census tract, with census tracts designed to be stable and homogeneous "neighborhoods". This paper is also the first to use statewide proposition voting outcomes to study demand for public education funding, and the first to empirically test for the effect of private schools on voter support for public school provision.

In all specifications, I use a fixed effects approach similar to that taken by Brunner et al. (2011) in estimating the effects of unemployment on democratic voting, in contrast to the cross-sectional approach taken in the prior environmental voting literature. I am able to construct a panel over propositions by using a time-varying measure of income and other covariates created from various estimates provided by the American Community Survey, in place of the static decennial census estimates. The use of fixed effects allows for control of omitted variables that are a concern in the cross-sectional studies, particularly those relating to Tiebout sorting to the extent that local and statewide public goods expenditures are substitutable (Tiebout, 1956). For instance, high income households may choose to live in communities with a high level of local spending on public safety, perhaps making them less likely to support statewide funding. More generally, households may choose where to live based on local amenities including environmental quality and schooling options. Community fixed effects control for local expenditures and other community specific features, which change more slowly than annual household incomes.

For ballot propositions regarding environmental quality or protection, I find significant differences between the income-voter support relationship for regulatory and fiscal propositions. For regulatory propositions, voter support is modestly increasing in income up to a certain level. This relationship is consistent with additional environmental regulation increasing consumer prices, or being perceived as having such an effect, and disproportionately affecting the utility of lower income households. For fiscal propositions, defined as those which involve either a direct increase in income taxes, the issuance of bonds, or a specific spending quota to be fulfilled by the state or local general fund, I find evidence of a U-shaped relationship. Voter support first decreases with income up to a certain income level and then begins to increase with additional income, indicating that households towards the middle of the income distribution are least supportive. This finding is consistent with the combined effects of a low tax burden on poor households and a low marginal utility of wealth among rich households. Intuitively, income plays a dual role in the case of fiscal propositions: income itself and the “price” of additional public good provision.

All propositions pertaining to public education, in the sample used in this paper and typically more broadly, have fiscal implications as they most often involve bonds or income taxes at the state level and income or property taxes at the local level (Moser and Rubenstein, 2002). As such, I likewise find a significant U-shaped relationship between income and voter support for public education propositions. However, as the availability of private substitutes increases, namely when there are more non-religious private schools in the area surrounding a neighborhood, the effect of high income on voter support for public education is moderated and eventually reversed. This finding is consistent with wealthy households substituting toward private schools and no longer receiving direct benefits from public education funding that counteract the increases in their tax burdens. Increases in private school availability may thus decrease public school funding, and worsen inequality in educational quality among rich and poor households.

For both environment and education related propositions, the findings summarized above are robust to a number of changes in specification, including the use of an extended set of fixed effects to mitigate concerns regarding spatial correlation, regression weights, and alternative measures of neighborhood income. I also find that within the categorization of fiscal propositions, voting patterns do appear to be common across bonds and direct income tax increases, suggesting that voters are aware of the fiscal implications of bonds. Lastly, I provide evidence that my results are not driven by either voter turnout or voting along party lines.

The following section provides a simple conceptual framework to motivate the empirical analysis, based on individual utility maximization in different ballot proposition scenarios. Section 3 summarizes the data used in the analysis and the process of combining precinct-level voting results with census-based demographic and income data. Section 4 presents the empirical results and robustness checks, and finally section 5 concludes.

1.2 Conceptual Framework

Community or neighborhood voting outcomes are the sums of the individual voting decisions of their residents. For each ballot proposition, an individual voter simply decides between the status quo and the proposed legislation by choosing the option that maximizes her utility. The legislation affects not only the provision of the public good but also potentially the prices of private goods or taxes, and the role of income differs accordingly. Utility is further affected by the availability of private substitutes, as individuals who choose a private substitute do not benefit directly from increased public provision. Income affects the ability of an individual to pay for a preferable substitute, and thus the role of income in the voting decision is further complicated. The following simple framework clarifies these mechanisms.

1.2.1 Individual Voting Behavior

Within a given neighborhood or community, denote individuals or households by $i = 1, ..., N$. Voter i will support a particular proposition if and only if it increases her utility, that is if the associated change in her utility, ΔV_i, is positive. The probability of an individual voting in favor is thus:

$$\Pr(vote_i = yes) = \Pr(\Delta V_i > \epsilon_i)$$

where ϵ_i is a randomly distributed error term.

Each individual chooses a level of consumption of a purely private good, c_i, and enjoys amenities or services at quality q_i. A certain level of quality is provided publicly, such as air or water quality, or the level of educational quality provided by public schools, but in some cases the individual may be able to substitute with a higher private level. The individual chooses consumption and quality to maximize utility subject to her budget constraint:

$$\max_{c_i, q_i} U(x_i, c_i, q_i) \text{ s.t. } s(q_i) + pc_i = y_i - t(y_i)$$

where x_i is a vector of individual-specific characteristics that account for preference heterogeneity, $s(q_i)$ denotes the amount spent on quality, p denotes the price of the private consumption good, y_i is income and $t(y_i)$ the total tax burden faced by individual i. I make the standard assumptions that both the private consumption bundle and the level of quality are associated with diminishing marginal utility: $\partial U/\partial q_i$, $\partial U/\partial c_i \geq 0$ and $\partial^2 U/\partial {q_i}^2$, $\partial^2 U/\partial {c_i}^2 \leq 0$.

For a pure public good or amenity with no private substitute, such as air quality, all individuals enjoy the same publicly provided quality with $q_i = Q$ and $s(q_i) = 0$ for all i. Consequently $c_i = (y_i - t(y_i))/p$ and i's indirect utility is simply:

$$V_i = U(x_i, (y_i - T(y_i))/p, Q)$$

First consider a regulatory proposition that increases non-substitutable Q but also prices of private consumption, p. An example of such a proposition would be a renewable resource portfolio standard, as appeared on the November 2008 California ballot, that improves air quality but potentially raises the price of electricity. In general, the change in individual utility associated with a regulatory proposition is approximated by:

$$\Delta V_i = \frac{\partial U}{\partial q_i}\Delta Q + \frac{\partial U}{\partial c_i(y_i)}\left[\frac{-(y_i - t(y_i))}{p^2}\right]\Delta p \qquad (1)$$

The first term in the above expression is clearly positive, and the second negative, when $\Delta Q > 0$ and $\Delta p > 0$. However the magnitude of the second term depends on income. Higher income implies a greater level of consumption of private goods, which in turn implies a lower marginal utility of consumption.

A greater level of consumption is also associated with more exposure to price changes in absolute terms though, as wealthier individuals consume more of the private good. The net effect of income is thus ambiguous, and in practice depends on the income-sensitivity of consumption of the good exhibiting the price change. Δp is likely to be relatively small though, so any dependence of ΔV_i on income may be minimal in comparison to other factors.

Now consider instead a proposition that funds an increase in the non-substitutable publicly provided level of quality with an explicit increase in income taxes, the issuance of government bonds, or a funding quota that draws from the state general fund. These fiscal propositions all entail an increase in current or future taxes, or the redirection of existing tax-based funds.[1]. The functional effect is similar and the change in utility is approximated by:

$$\Delta V_i = \frac{\partial U}{\partial q_i}\Delta Q + \frac{\partial U}{\partial c_i(y_i)}\left[\frac{-1}{p}\right]\Delta t(y_i) \qquad (2)$$

Again the first term is positive and the second unambiguously negative when $\Delta G > 0$ and $\Delta t(y_i) > 0$. As with the price increase, the magnitude of the second term decreases as the marginal utility of consumption falls, which occurs as income increases. However, since taxes are determined by income, the actual level of $\Delta t(y_i)$ is most likely increasing in income. If the tax rate is a constant fixed percentage, τ, then $\Delta t(y_i) = \Delta\tau \cdot y_i$ and the marginal effect of a unit increase in income is a positive constant, $\Delta\tau$. Moreover if the tax rate is progressive, as is very much the case for California state income taxes[2], then the magnitude of the tax increase in absolute terms may be even greater for wealthier individuals. The effective cost of the proposition is increasing in income, so income enters utility both as the means to private consumption and as the equivalent of a "price". The overall effect of income on ΔV_i depends on whether the marginal utility effect or the tax price effect dominates, but the change in utility is maximized if either $\partial U/\partial c_i(y_i)$ or $\Delta t(y_i)$ goes to zero. This corresponds with very high or very low income respectively, suggesting that individuals in the middle of the income distribution may be least likely to benefit from such a proposition.

Some publicly provided goods or amenities are substitutable with private equivalents. Public education in particular has a clear private substitute,

[1] Detractors of referendum and initiative voting often argue that voters do not understand the fiscal implications of bonds. In the empirical section, I explore whether voters indeed respond to these different types of fiscal propositions in the same way.

[2] The current California state income tax rate ranges from 1% for the lowest levels of income to 12.3% for individual income over $508,500.

namely private school. In these cases an individual can utilize the publicly provided level with $q_i = Q$ and spend none of her private income net of taxes, or she can pay privately for her own utility maximizing level of quality. For individuals who choose not to pay for a private substitute, changes in utility associated with a ballot proposition are simply as above in equations (1) and (2) for regulatory and fiscal propositions respectively.

For those who do choose a private substitute level of quality, normalizing the expense of an additional unit of quality to 1, indirect utility is given by:

$$V_i = V(x_i, y_i - t(y_i), p)$$

For these individuals, the change in utility associated with a fiscal proposition that increases the publicly provided level of quality as well as taxes is approximated by:

$$\Delta V_i \;=\; -\frac{\partial V}{\partial(y_i - t(y_i))}\Delta t(y_i) \tag{3}$$

The change in utility is clearly negative, as substituting individuals receive no benefit from the increase in Q to compensate for the decrease in utility associated with the greater tax burden. Again this is the case moreso if the tax rate is progressive.

Note that equation (3) ignores the possibility that individuals may be concerned with the publicly provided level of quality even if they do not take advantage of it directly. It might certainly be the case that people care about public education funding even if they do not have children in public school. However, unless such other-regarding behavior depends on income, individual utility associated with the benefits of a higher publicly provided level of quality to others would simply be a constant term added to each of equations (1), (2), and (3). It would not affect the comparison of these expressions with one another.

Given $\frac{\partial U}{\partial q_i} > 0$, it must be the case that $q_i \geq Q$ for all i, so substitution is only plausible for individuals with income high enough to pay for quality exceeding the publicly provided level. No individuals for which $y_i \leq s(Q) + \delta$, where δ is some marginal amount of quality, will choose the private substitute. Thus the probability that an individual will substitute is increasing in income:

$$\partial \Pr(q_i > Q)/\partial y_i > 0$$

and so

$$\partial \Pr(\Delta V_i > \epsilon_i)/\partial y_i < 0$$

With private substitutes, voter support is declining in income. Greater availability of substitutes will only increase available quality and the likelihood of private substitution, $\Pr(q_i > Q)$, so the negative effect of income on voter support will be more pronounced.

Although proposition voting decisions are simple binary choices, it is sometimes the case that propositions on a single ballot interact or compete with one another. Most explicitly, in some cases only the initiative with the greatest margin of victory among competing initiatives will be enacted[3]. The above structure could be modified to include multi-dimensional comparisons or comparisons between combinations of vote choices, but the complication provides no additional insight and is beyond the scope of this paper. From an empirical perspective, proposition fixed effects will capture the main effect of depressed overall support in the presence of competing initiatives.

1.2.2 Aggregation and Estimation

Actual voting outcomes are typically not available at the individual level due to confidentiality, so it is necessary to translate the above individual income relationships into aggregate probabilities. The share of votes in favor of a proposition in a given community is the sum of individual indicators:

$$\begin{aligned} S &= \sum_{i=1}^{N} I(vote_i = yes)/N \\ &= \sum_{i=1}^{N} I(\Pr(\Delta V_i > \epsilon_i))/N \end{aligned}$$

which is a function of individual characteristics.

The standard approach to estimation with aggregate data is to assume a representative voter, with characteristics equal to some summary value of the population distribution, and logistic errors. The predictions of the model are

[3]On the 2012 California ballot, for example, Jerry Brown's income tax increase for education was seen by many as directly competing with Molly Munger's income tax increase for education, with campaigning and opinions in favor of one often citing its superiority over the other.

thus testable by estimating the following equation:

$$\ln \frac{S}{1-S} = f(\bar{x}, \bar{y}, \Delta Q, \Delta \bar{t}(y), q) \tag{4}$$

where $\bar{x}$ and $\bar{y}$ are representative values of demographic characteristics and income respectively, ΔQ is the additional level of quality provided by the proposition, $\Delta \bar{t}(y)$ is the associated fiscal burden, and q is the availability of the private substitute. The transformation is unlikely present any econometric problems in this context as voting shares are most often concentrated around 0.5 and are very rarely equal to zero or one.

The assumption of a representative voter is not grounded in realism, and a large literature explores the "ecological fallacy" of making inferences about individuals from aggregate data (Kramer, 1983). However, in the context of proposition voting, Fischel (1979) and Bergstrom et al. (1982) provide evidence that aggregate data can lead to similar conclusions as those generated by survey data on individual voting decisions. Moreover, as mentioned previously, the units of aggregation for this paper are fairly small, so the assumed representative voters more accurately represent a greater proportion of the population. The data are at the census block group level, one level of disaggregation finer than the unit designed by census administrators to be a homogeneous neighborhood.

One caveat regarding aggregation must be noted though. Without individual level data, it is not possible to tease apart an individual's consideration of her own characteristics from consideration of her neighbor's characteristics. For example, a voter may oppose regulation of a particular industry because she is employed by that industry, or because many of her neighbors are. Likewise, a voter may approve additional funding for education because she has children or because there are many children in her immediate community. Isolation of these effects would require paired individual and aggregate data, but the extent to which such other-regarding behavior depends on the proximity of the others regarded would be an interesting topic for future research.

1.3 Data

1.3.1 Voting Shares

Voting data is taken from the Statewide Database managed by the Center for Research at the University of California Berkeley School of Law, maintained for the purposes of congressional redistricting. The database provides the total number of registered voters, the number of votes cast for each political candidate, and the number of votes in favor and against every ballot proposition at the precinct level in all statewide elections. For the 2012 general election, there were approximately 23,000 consolidated registration ("SR") precincts covering California, with an average of 764 registered voters and 558 actual votes cast per precinct[4].

Voting precincts do not always coincide with census geography so I convert the data to 2000 census block groups using election specific conversion files prepared by the Statewide Database. The conversion file provides the fraction of a voting precinct whose voters are registered to an address geocoded to each census block. I multiply these fractions by the total number of "yes" votes and "no" votes in each precinct, thus assigning each vote to a particular census block, and sum up to the block group level. The 2012 primary and general election geographical conversion files use 2010 census geography, which I convert to 2000 census block groups based on percentages of intersecting land area.

I use voting outcomes on all environment and education-related propositions that appeared on the ballot in both primary and general elections between 2006 and 2012, where the categorization depends on the inclusion of any environment or education claims appearing in the official voter information guide prepared by the Secretary of State. Of the 63 propositions appearing on California ballots in this time frame, around half pertained to the provision of public goods including health and safety, transportation, the environment, and public education. Table 1 briefly describes these propositions and provides the mean voter approval rate across block groups as well as the overall statewide approval rate. For all propositions, the mean block group approval rate is similar to the statewide outcome, as expected. For both environmental and education propositions, the outcomes range from strongly positive as with the 2006 bond act for highway safety and air quality improvements (proposition 1B), to strongly negative as with the 2008 standard for utility company renewable resource portfolios (proposition 7) and the 2010 proposed suspension of the Global Warming Solutions Act (proposition 23).

Figures 1-3 show the degree of heterogeneity in voter support across block groups for these three particular propositions. While proposition 1B appears fairly universally popular, and proposition 7 relatively universally unpopular, there is nonetheless significant variation throughout the state. Approval of proposition 23, which in this case represents an anti-environmental position,

[4]Ballots cast by mail are all attributed to the voter's registration address, although in 2006 a handful of counties, including Los Angeles, did not require mail ballots to be reported as such. These votes are thus dropped from the sample.

Table 1.1: Public Good Ballot Propositions and Voting Summary Statistics

Proposition	Description	**Voter Approval Rate** Mean BlkGrp	Statewide
Environment			
2006 1B	bonds for highway, port safety and air quality	0.628	0.614
2006 1E	bonds for flood control and water quality	0.655	0.642
2006 84	bonds for water quality and natural resources	0.571	0.538
2006 87	oil producer tax for clean energy program	0.479	0.454
2008 1A	bonds for high speed rail	0.542	0.527
2008 7	renewable resource portfolio standards	0.369	0.355
2008 10	bonds for alternative fuels	0.426	0.405
2010 21	vehicle license fees to fund state parks	0.431	0.427
2010 23	suspend CA Global Warming Solutions Act*	0.369	0.384
2012 37	mandatory labeling of GE food	0.502	0.486
2012 39	multi-state business taxes for clean energy	0.631	0.611
Education			
2006 1D	bonds for education facilities	0.604	0.569
2006 81	bonds for public libraries	0.509	0.473
2006 82	income tax increase to fund public preschool	0.431	0.392
2006 88	parcel tax to fund k-12 education	0.256	0.233
2008 92	community college funding, fees, governance	0.459	0.427
2012 30	income tax increase for general fund, education	0.578	0.554
2012 38	income tax increase for education	0.312	0.287
Other			
2006 1A	transportation funding protection	0.759	0.770
2006 1C	bonds for emergency shelter	0.614	0.578
2006 86	cigarette tax to fund children's hospitals	0.491	0.483
2008 91	transportation funding protection	0.420	0.416
2008 2	standards for confining farm animals	0.642	0.635
2008 3	bonds for children's hospitals	0.577	0.553
2010 22	local public safety and transportation funding	0.601	0.607
2012 29	tobacco tax for cancer research	0.500	0.497

* Votes against proposition 23 are the pro-environmental position, so "yes" and "no" votes are reversed in all analyses.

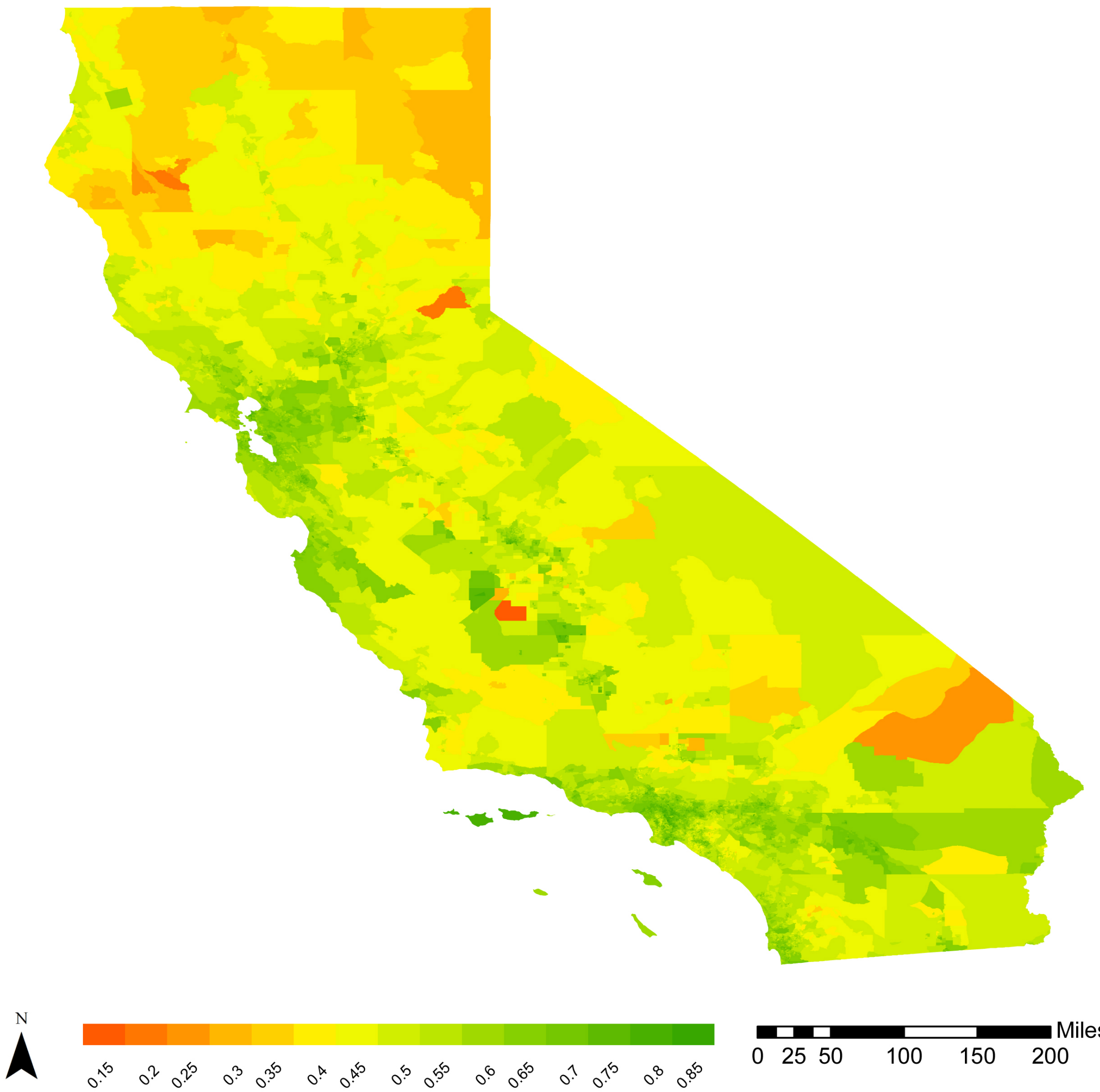


Figure 1.1: Block Group Share Voting in Favor of 2006 Proposition 1B asking voters "Should the state sell $19.9 billion in general obligation bonds to fund state and local transportation projects aimed at relieving congestion, improving movement of goods, improving air quality, and enhancing safety and security of the transportation system?"

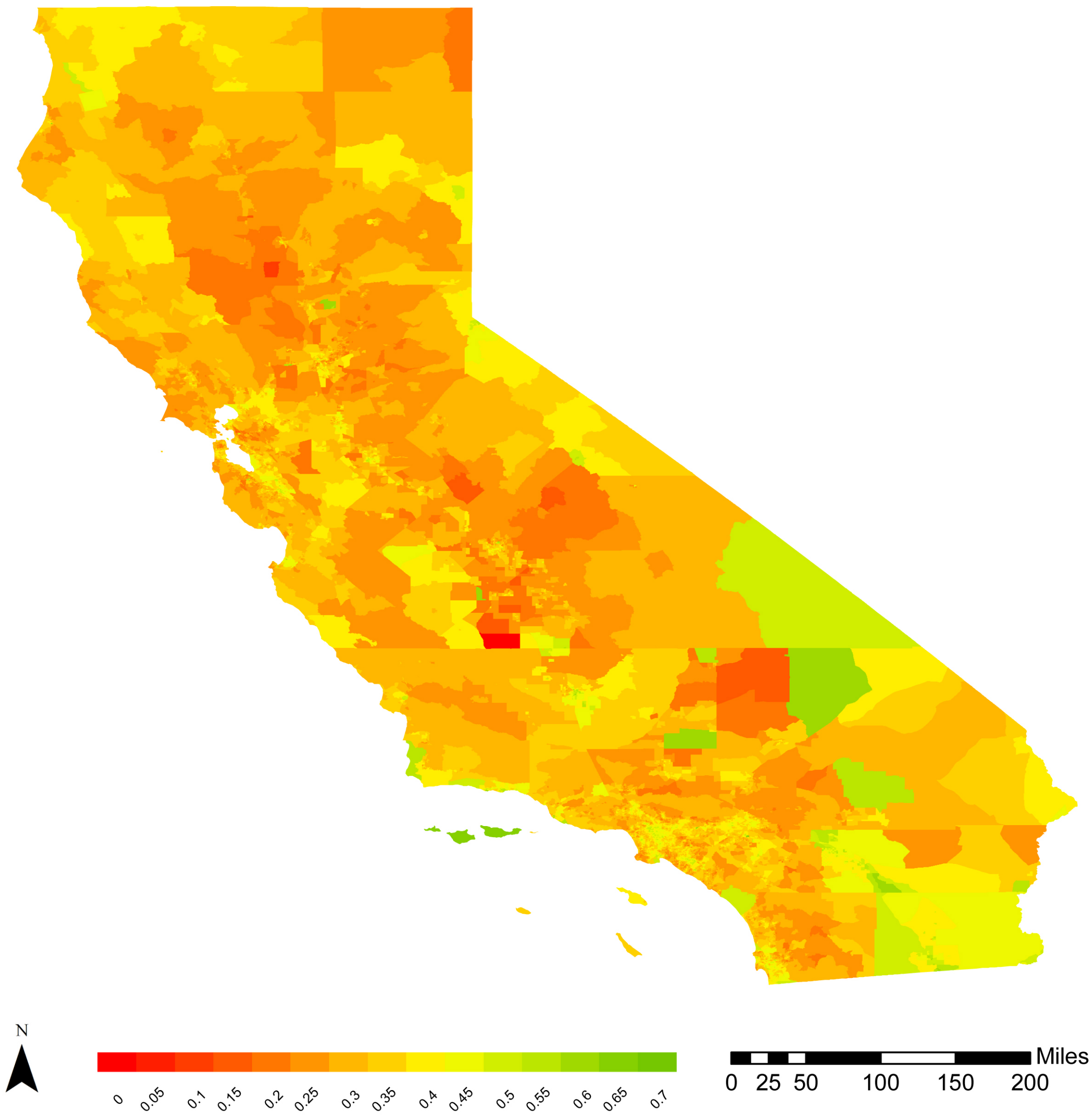


Figure 1.2: Block Group Share Voting in Favor of 2008 Proposition 7 asking voters "Shall government-owned utilities be required to generate 20% of their electricity from renewable energy by 2010, a standard currently applicable to private electrical corporations? Shall all utilities be required to generate 40% by 2020 and 50% by 2025?"

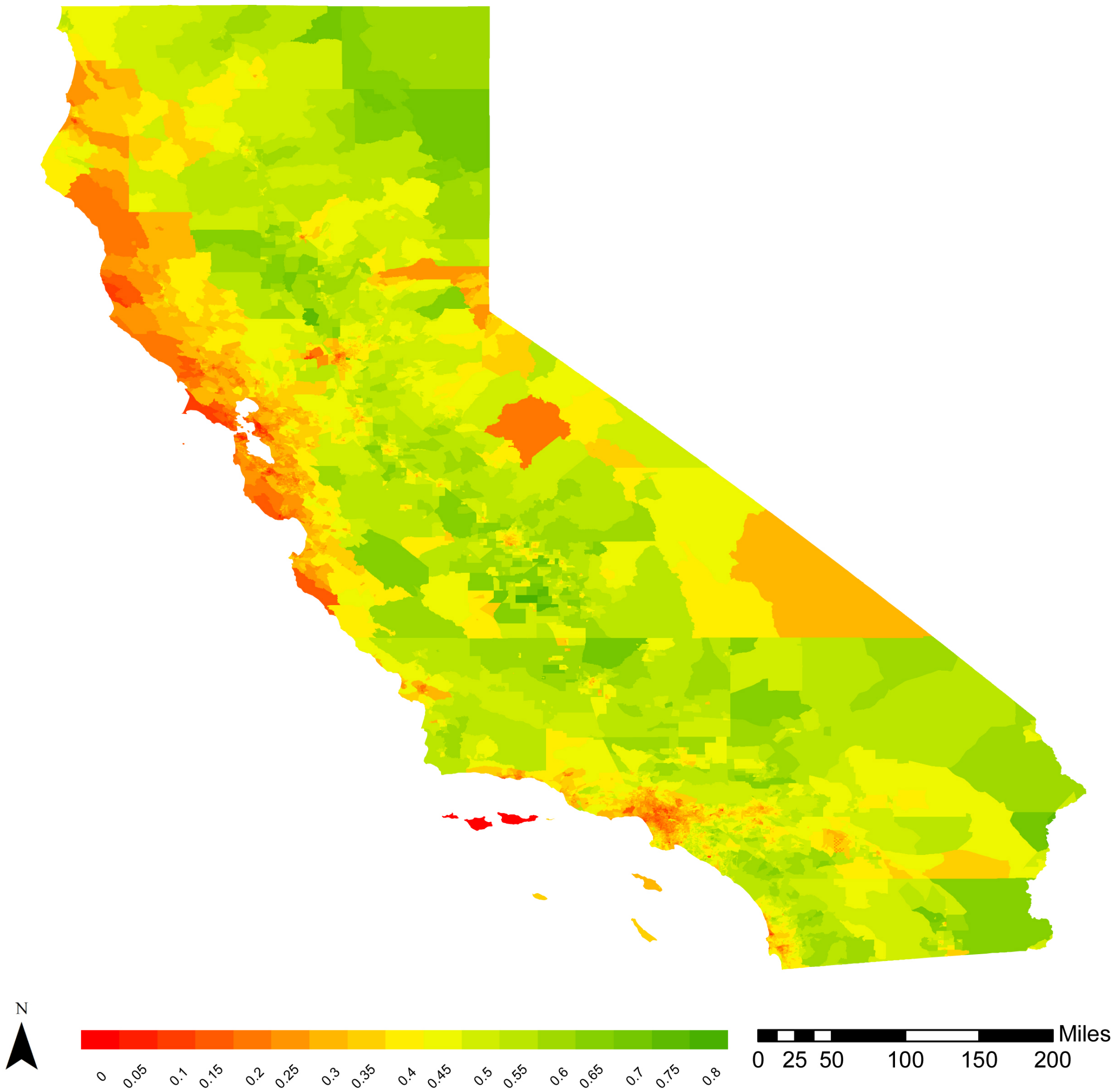


Figure 1.3: Block Group Share Voting in Favor of 2010 Proposition 23 asking voters "Should the state suspend implementation of Air Pollution Control Law (AB 32) requiring major sources of emissions to report and reduce greenhouse gas emissions that cause global warming until unemployment drops to 5.5 percent or less for a full year?"

is much more variable. There does appear to be a concentration of more pro-environmental voting along the coast and in urban areas, as may be expected, and this spatial correlation is addressed in the empirical analyses.

The environmental propositions span a range of goods or amenities, including air and water quality, clean energy, and public open space. The targets of the education-related propositions range from pre-school to community college to public libraries. Across all public good propositions, there is a fairly even split between regulatory and fiscal propositions although as noted this is not true for public education propositions alone. Also, bonds for purposes other than public education appear only in 2006 and 2008. To ensure that results are not driven by any particular misclassification, primary specifications are all run excluding each proposition one at a time, with no significant impact on findings.

1.3.2 Demographic and Economic Characteristics

Demographic and income data are assembled from the American Community Survey (ACS), the dynamic counterpart to the decennial census. The ACS data involves a tradeoff between temporal accuracy and geographical disaggregation. Annually released 5-year estimates provide data at the census block group level but rely on data collected in the title year and the previous 4 years. The 2009 estimates, for example, use data collected between 2005 and 2009. 1-year estimates are more current as they are assembled only from data collected in the title year, but are only available for geographies with population greater than 60,000 due to sample size constraints. Geographically contiguous statistical areas known as Public Use Microdata Areas (PUMAs) are designed to divide states into regions of around 100,000 people and are the finest scale at which the 1-year estimates offer complete coverage of the population. To illustrate the geographical scale of the different ACS data products, Figure 4 maps PUMA and block group boundaries in Los Angeles County in 2012. Los Angeles county is by far California's most populous, housing approximately a quarter of the state's total population.

To generate a reasonably current measure of demographic and economic characteristics at the block group level, I combine 5-year and 1-year estimates. The 5-year estimates capture the slower process of relative neighborhood compositional shifts, while the 1-year estimates capture year to year income shocks. For each variable taken from the ACS, the ratio of each block group's 5-year value to its overall PUMA's 5-year value is multiplied by its overall PUMA's 1 year value. I use the 2009 5-year estimates, which are based on data from 2005 to 2009, to generate values in 2006 and 2008, as 5-year estimates are only

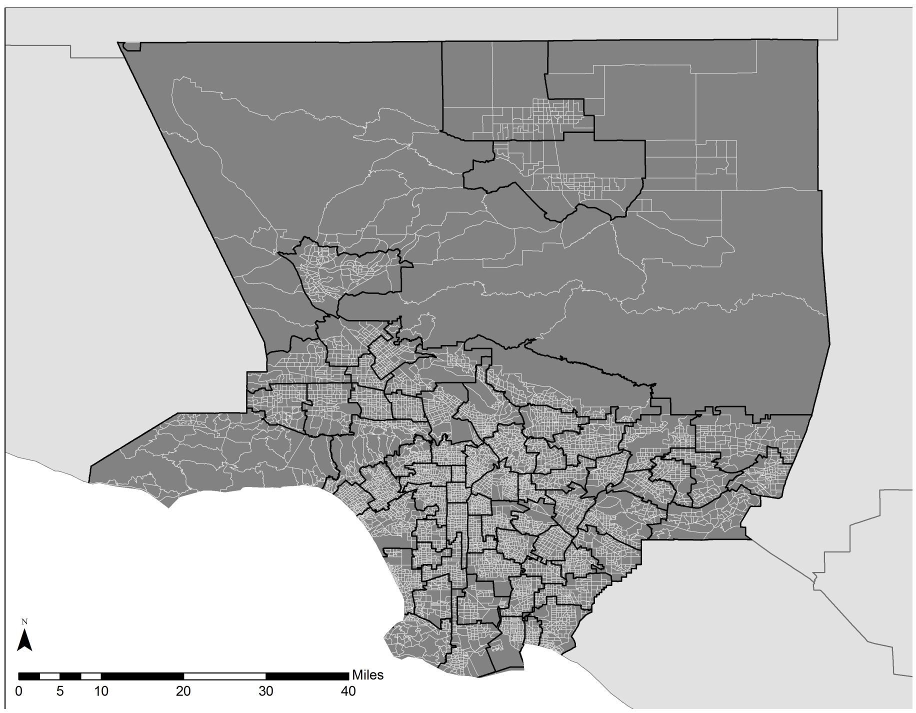


Figure 1.4: 2010 Census Block Group and Public Use Microdata Area (PUMA) Boundaries for Los Angeles County

available starting in 2009. All boundaries are converted to 2000 census geography, based on the fraction of intersecting land area for 2010 block groups that overlap with more than one 2000 block group or vice versa.

The ACS offers a very rich set of potential covariates, but I focus only on those variables found in the prior literature to be significant predictors of environmental voting behavior or public education expenditures. These include age, sex, children, race, ethnicity, education, house ownership, and employment in a particularly environmentally damaging sector, namely agriculture, forestry, mining and resource extraction, or utilities. Table 2 provides summary statistics of income and these additional covariates across all California block groups over the sample time frame. The recession beginning in 2009 is apparent in the data, with median household income notably decreasing between 2008 and 2010. Overall, the California population is increasing, diversifying in terms of racial composition, and becoming more college educated over the time period. The fifth and ninety fifth percentile statistics reveal some of the heterogeneity across block groups in terms of all of the characteristics listed.

Table 1.2: Demographic Summary Statistics Across All Block Groups

	Median Across Block Groups				5th %ile	95th %ile	Statewide
	2006	2008	2010	2012	2012	2012	2012
Population	1,118	1,129	1,146	1,290	641	2,976	38.0M
Households	384	383	389	403	223	992	12.6M
Median HH Income	63,791	64,216	60,080	58,274	29,595	174,938	58,328
% Income>$100k	19.6	22.7	21.5	22.9	4.3	55.0	27.5
% Income<$40k	28.2	30.7	33.3	33.2	12.2	65.3	35.2
Median Age	35.5	34.9	36.1	36.0	26.3	47.9	35.5
% Male	49.6	49.7	49.5	49.4	42.8	56.4	49.7
% HH with Children	57.1	56.4	54.0	55.3	19.5	100	36.3
% Black	1.3	1.3	1.5	1.8	0.0	16.1	6.0
% Asian	4.9	4.8	5.4	6.4	0.0	34.1	13.5
% Hispanic	24.2	23.9	24.0	28.6	5.5	80.4	38.2
% Employed in Polluting Sectors	6.3	6.5	7.6	8.5	3.9	16.6	7.1
% College Educated	39.0	41.0	41.7	41.6	15.1	65.9	38.9
% w/ Children in Private School	8.3	8.5	7.9	7.6	0.0	37.1	4.1
% Owner Occupied	61.4	59.3	57.5	58.3	17.5	86.9	54.0

To better demonstrate the geographical variation in the variable of primary interest, Figure 5 maps 2012 block group median household income across the state. Note that high and low median income block groups are dispersed throughout the state, although the very wealthiest and the poorest do tend to be more concentrated around urban areas along the coast. Similarly, Figure 6 maps changes in block group median household income between 2006 and 2012. There is a significant amount of income variation over time, and moreover sizable temporal changes appear to be well distributed across the state, and within PUMA boundaries.

1.3.3 Private Schools

The California Department of Education requires all elementary and secondary schools enrolling six or more students to file an affidavit each year declaring their status. The department website provides an annual database of all such schools including their addresses, student enrollment, number of teachers, and classification as religious or non-religious institutions. I use this database to generate a measure of private school availability that varies over time and across census block groups. For each block group in each year, I sum the number of religious and non-religious schools with addresses geocoded within a five mile buffer around each block group's boundary.

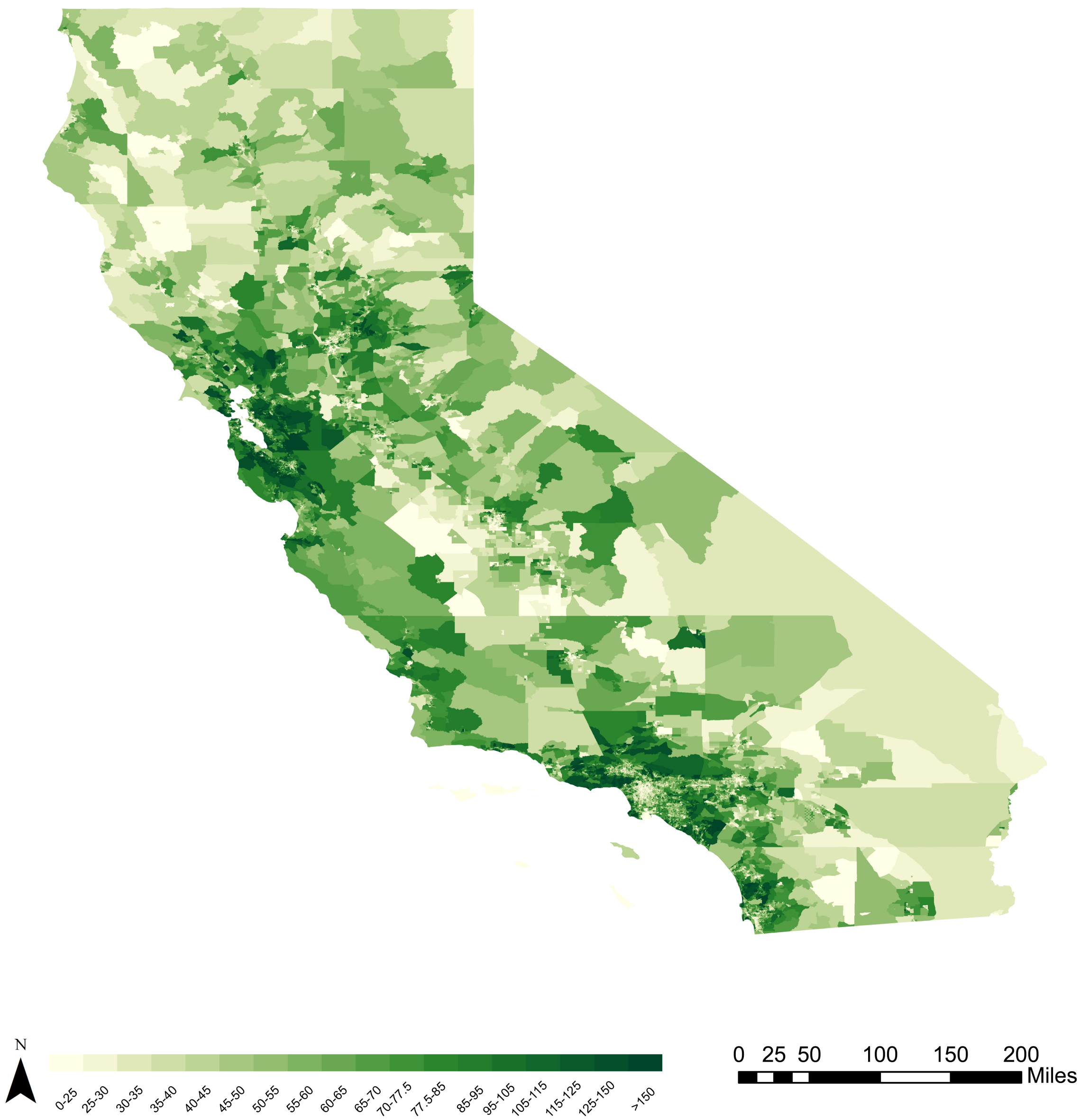


Figure 1.5: Median Household Income (thousands) at the Block Group Level in 2012

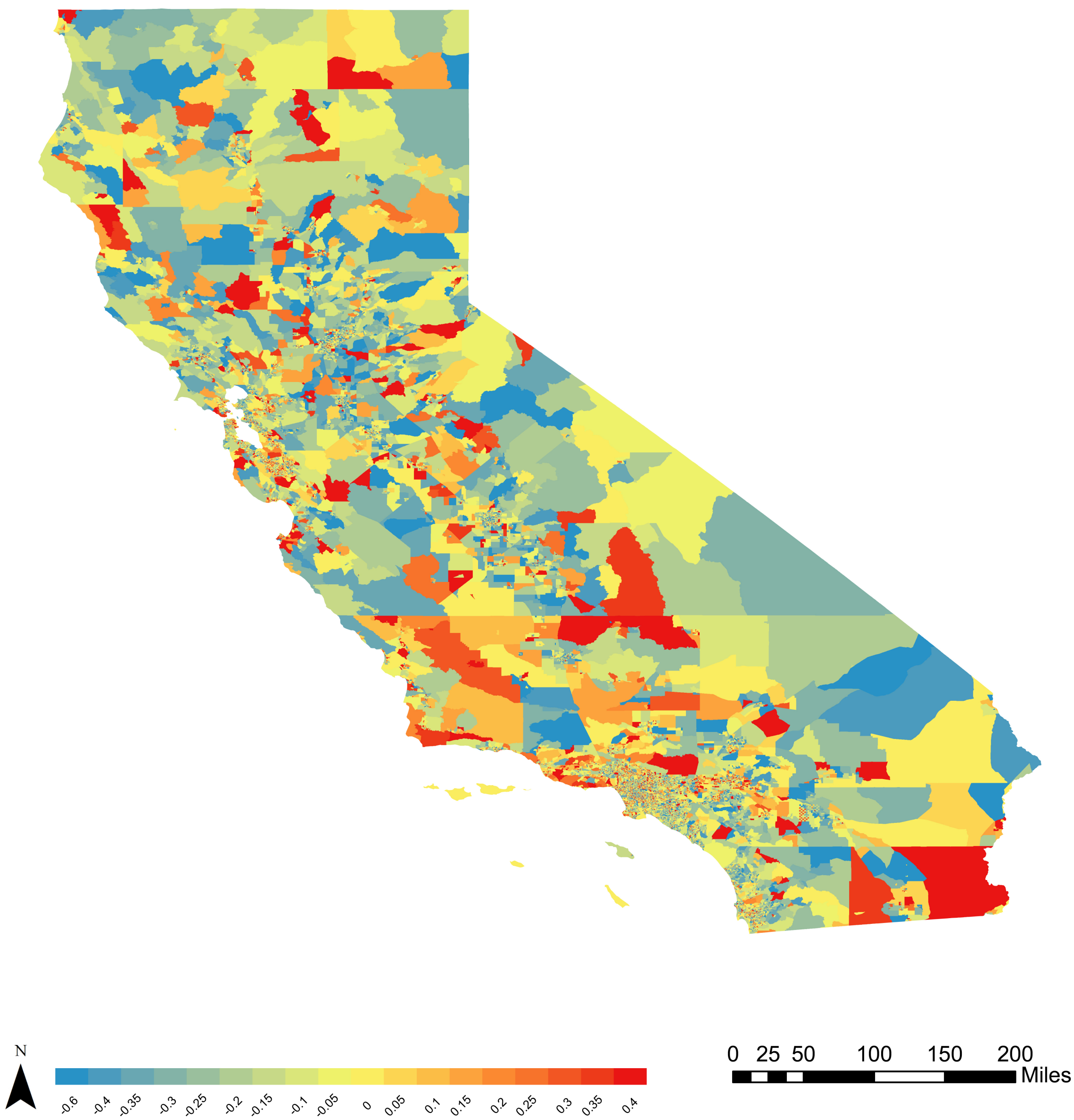


Figure 1.6: Proportional Changes in Median Household Income at the Block Group level between 2006 and 2012

Figure 7 shows the distribution of this measure of private school availability in 2012, separately for religious and non-religious schools. For both school types, availability ranges from zero to over 60 schools in the 5 mile buffer surrounding a block group, although for non-religious private schools the frequency drops at around 20. Figure 8 shows the distribution of changes in private school availability between 2006 and 2012, with an apparent decline in the number of religious schools overall and an increase in the number of non-religious schools. The greatest mass is at no change in private school availability, which is unsurprising given the relatively short time interval.

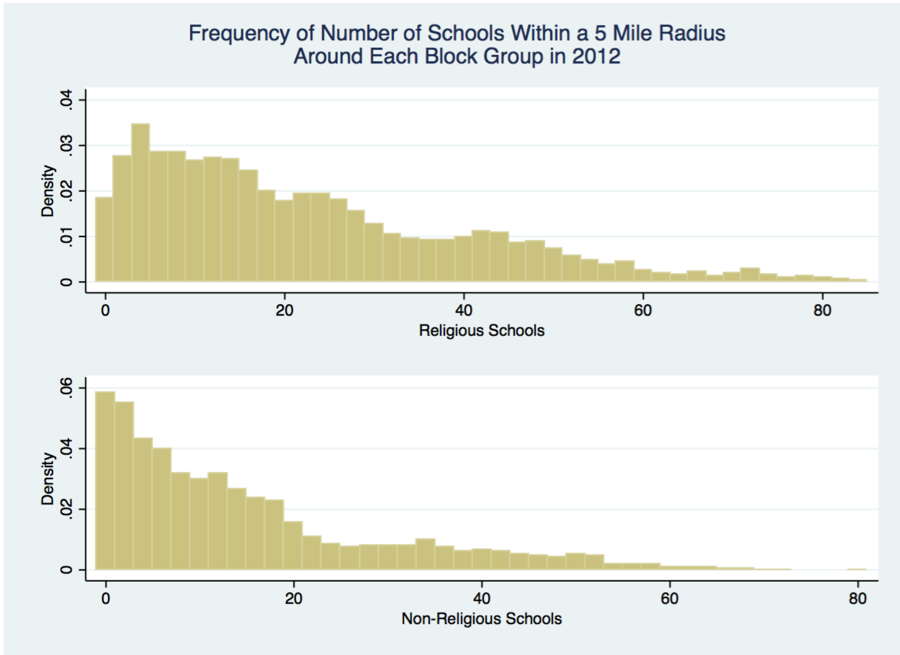


Figure 1.7: Number of Schools Within a Five Mile Radius of Each Block Group in 2012

This measure is admittedly not ideal for geographically large block groups, where households may be quite far from other locations within their own block group, let alone from locations in a buffer extending beyond it. Such groups coincide with more rural areas though, where households may be willing to drive a further distance to reach school. Results are not sensitive to choosing a smaller or slightly larger buffer, although geographical variation is significantly diminished at a buffer radius greater than 10 miles. In the largest counties in California, 60-75% of children aged 5-15 live within 2 miles of their school (McGuckin, 2013) so a much larger buffer would be inappropriate anyway.

The count of nearby private schools is a much less direct measure of private substitution than enrollment, but I use the school count instead of enrollment for a number of reasons. First, neighborhood-level enrollment is clearly an outcome of neighborhood-level income itself. The number of schools in a fairly large surrounding area, however, is less likely to respond to annual changes in the income of a block group's residents. Indeed the simple correlation between private school availability and median census block group income is very low, particularly after accounting for geographical fixed effects. Private school en-

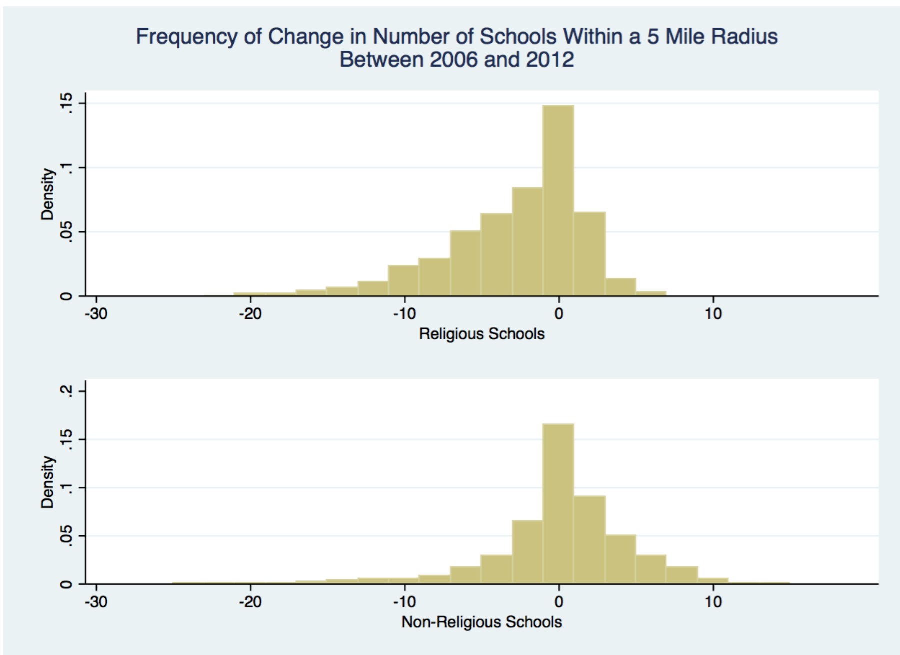


Figure 1.8: Changes in Number of Schools Within a Five Mile Radius of Each Block Group between 2006 and 2012

rollment also excludes the preferences of households with young children not yet enrolled in school, and of future parents. These voters may have strong preferences regarding public education funding despite not currently having school-age children.

1.4 Empirical Analysis

In line with the prior literature based on the the model developed by Deacon and Shapiro (1975), my basic specification is a simple linear approximation of equation (4). I estimate the log odds of approval at the census block group level as a function of block group level characteristics:

$$\ln \frac{Y_{bp}}{N_{bp}} = \beta_1 X_{by} + \beta_2 I_{by} + \delta_b + \lambda_p + \epsilon_{bp} \tag{5}$$

where Y_{bp} is the number of votes cast in favor of proposition p in block group b, N_{bp} is the number of votes against, X_{by} is a vector of demographic characteristics describing the block group in the year y in which the proposition appeared on the ballot, I_{by} is a vector of measures of the income distribution, δ_b are geographic fixed effects, and λ_p are proposition fixed effects, which capture the changes in the level of publicly provided goods, ΔQ. My primary specifications use block group median household income and its square only, as the inclusion of higher order polynomials yields similar qualitative conclusions but confuses the interpretation.

In order to test the implications of equations (1) and (2) in the context of environmental propositions and public good propositions overall, for which there are both fiscal and regulatory examples in my sample, I further include the interaction of income with an indicator variable for fiscal propositions:

$$\ln \frac{Y_{bp}}{N_{bp}} = \beta_1 X_{by} + \beta_2 I_{by} + \beta_3 (I_{by} * f_p) + \delta_b + \lambda_p + \epsilon_{bp} \tag{6}$$

where f_p is equal to one if proposition p involves income tax increases, the issuance of bonds, or funding requirements that draw on the state or local general fund. The coefficients on uninteracted income thus measure the effect of income on support for regulatory propositions, and the interaction terms the differential effect of income on support for fiscal measures. In terms of the conceptual framework, $I_{by} * f_p$ proxies for $\Delta\bar{t}(y)$ in equation (4).

To test the implications of equation (3) in the context of public education propositions, I instead include the interaction of income with the availability of the private substitute:

$$\ln \frac{Y_{bp}}{N_{bp}} = \beta_1 X_{by} + \beta_2 I_{by} + \beta_3 (I_{by} * s_{by}) + \delta_b + \lambda_p + \epsilon_{bp} \tag{7}$$

where s_{by} is a continuous variable equal to the number of private schools in a 5 mile radius surrounding block group b in year y. Coefficients on uninteracted income thus capture the relationship between income and voter support for public education when no private substitutes are available.

For both environment and education propositions, I focus on specifications using census tract, rather than census block group, fixed effects. Census tracts are a step larger unit of aggregation than block groups, with approximately 7,000 of the former compared to 22,000 of the latter in California in 2012. Geographical fixed effects are intended to capture omitted variables describing neighborhood or community characteristics, and census tracts are designed with local input to represent stable and homogeneous communities. The omitted variables of concern, such as local amenities and expenditures on publicly provided goods, are thus likely to be captured by census tract fixed effects. Income variation across block groups within a tract is therefore useable for identification, but I include regressions with block group fixed effects for robustness.

Since spatial correlation is undoubtedly an issue here, given the maps presented in the previous section, I take additional steps to mitigate this concern beyond the inclusion of census tract or block group fixed effects. First, I also include specifications that further include county specific year fixed effects, to control for within county correlation in error terms that may vary over time. Second, standard errors for all regressions are clustered at the county level. This is likely to be an over-correction, which I use on the grounds of conservative inference.

1.4.1 Environmental Propositions

Table 1.3: Voter Support for Environmental Propositions

	(1) odds	(2) odds	(3) odds	(4) odds	(5) odds	(6) share
Median HH Income	-0.064**	0.088*	0.045	0.141*	0.030	0.018*
	(0.026)	(0.052)	(0.054)	(0.076)	(0.055)	(0.011)
Median HH Income^2	0.009	-0.038	-0.015	-0.048	-0.027	-0.008
	(0.012)	(0.026)	(0.026)	(0.044)	(0.026)	(0.005)
Fiscal × Income		-0.348***	-0.349***	-0.363***	-0.299***	-0.076***
		(0.069)	(0.068)	(0.065)	(0.067)	(0.014)
Fiscal × Income^2		0.115***	0.115***	0.121***	0.95**	0.025***
		(0.033)	(0.033)	(0.032)	(0.031)	(0.007)
Demographic Controls	Yes	Yes	No	Yes	Yes	Yes
Industry Controls	Yes	Yes	No	Yes	Yes	Yes
Fixed Effects	Tract	Tract	Tract	Blk Grp	Tract& Cnty-Yr	Tract
Observations	241,330	241,330	241,444	241,330	241,330	241,341

Columns 1 through 5 present estimates from linear regressions of the log-odds of the share of votes in favor, Column 6 presents estimates from a linear regression of the the share itself. Standard errors are clustered at the county level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

For comparison with the prior literature on voting on environmental propositions, I first estimate equation (5) with no interactions allowing for heterogeneity in the income voter support relationship between proposition types. This regression is the fixed effects version of the single proposition cross-sectional regressions of Deacon and Shapiro (1975), Kahn and Matsusaka (1997), Wu and Cutter (2011), etc. Results are reported in the first Column of Table 3. The coefficient on median household income is negative and significant at the 5% level, consistent with the more recent literature that uses similarly geographically disaggregated data. The square of median household income is not significantly associated with voting outcomes and the point estimate is close to zero.

Coefficients on other covariates are also consistent with the prior literature on environmental voting outcomes, and more broadly with trends in willingness to pay studies looking at the effects of individual level characteristics. Since these covariates are not the focus of this paper, I exclude them from the results table for readability. In all specifications, age is significantly negatively related with support for environmental protection, and the coefficient on the share of male residents is also negative although not always significant. The coefficient on education is robustly positive and significant, while shares of black, asian, and hispanic residents are not significant and with varying point estimates across specifications.

As a proxy for the potential costs of the propositions, taking the approach of Kahn and Matsusaka (1997), I also include shares of employment in industries most typically affected by environmental regulation. Since the coefficient estimates are consistent with both intuition and the prior literature, they are again omitted from the results table. Employment in agriculture, forestry, and fishing is strongly negatively correlated with voting in favor of environmental initiatives. Shares of employment in mining, oils and gas extraction, and utilities, are also negatively associated with the dependent variable, although the relationships are less significant. Interpretation of these coefficients is unclear, however, as individuals who work in these industries may simply not have strong preferences for environmental protection to begin with. Their demand for environmental quality may be low regardless of their employment in industries affected by regulation, so it may not be the implicit costs of regulation that deter them.

The second Column of Table 3 presents results from estimation of equation (6), including the interactions of income and its square with the indicator variable for fiscal propositions. While the coefficients on the uninteracted income terms are only minimally significant, both income and its square are strongly significantly related to voter support when interacted with the fiscal proposition dummy. These results indicate that the observed income effects in the prior voting literature are largely attributable to those propositions which include issuance of a bond or a direct increase in income taxes, rather than to propositions based on regulatory change. The relationship between income and voter support clearly differs depending on proposition type, and the difference is consistent with the implications of the conceptual model of Section 2.

For regulatory propositions, the share of pro-environmental votes is weakly increasing in income up to a certain level, suggesting that the effect of the marginal utility of consumption dominates the effect of the actual level of consumption in the face of potential price changes. More generally, income is not strongly correlated with voter support, as expected since perceived price changes are likely to be small. For fiscal propositions, on the other hand, the coefficients on income and its square are significant at the 1% level. The magnitudes of these coefficients also dominate the coefficients on uninteracted income and thus reverse the signs. Voter support decreases with income up

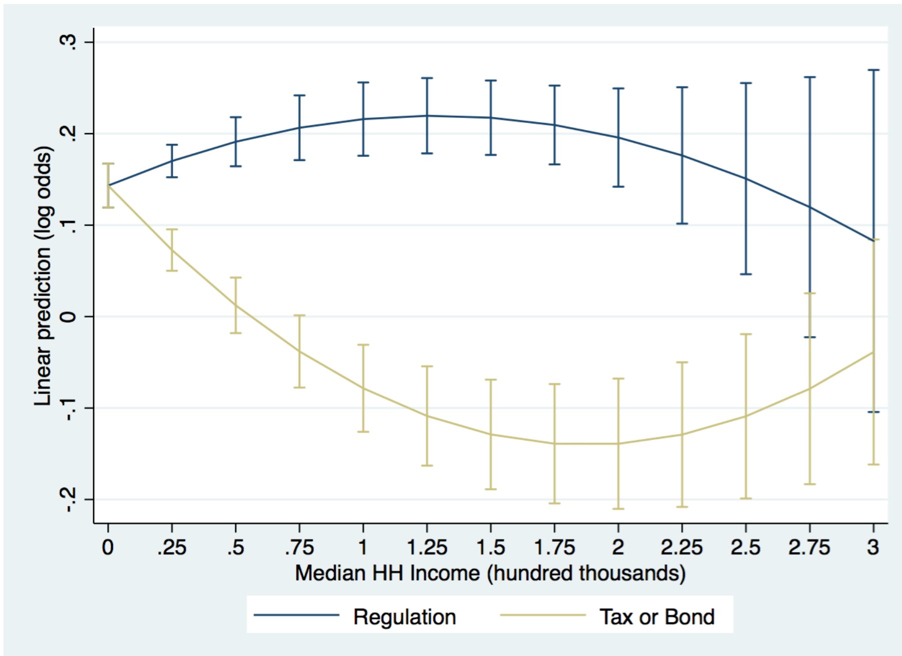


Figure 1.9: Effects of Median Household Income on Linear Predictions of the Log-Odds of the Share of Votes in Favor of Environmental Propositions, by Proposition Type

to a certain income level, beyond which increases in income are associated with greater voter support. Neighborhoods toward the middle of the income distribution tend to be the least supportive of environmental regulation in the face of an increased tax burden. Returning to the conceptual framework of Section 2, the evidence is consistent with the minimal tax burden dominating the voting decision among low income households, and the low marginal utility of consumption dominating among very high income households.

To illustrate the relationship more clearly, Figure 9 provides a graphical representation of the estimation results of Column 2. The upper line shows the relationship between income and voter support for regulatory environmental propositions while the lower line shows the relationship for fiscal environmental propositions. Standard error bars are calculated via the delta method. As the regression estimates indicate, the log-odds of the share of votes in favor is weakly increasing in income up to a point for regulatory propositions, but there is little evidence of an income effect beyond that point. The lower line, however, is clearly and significantly U-shaped, with the turning point

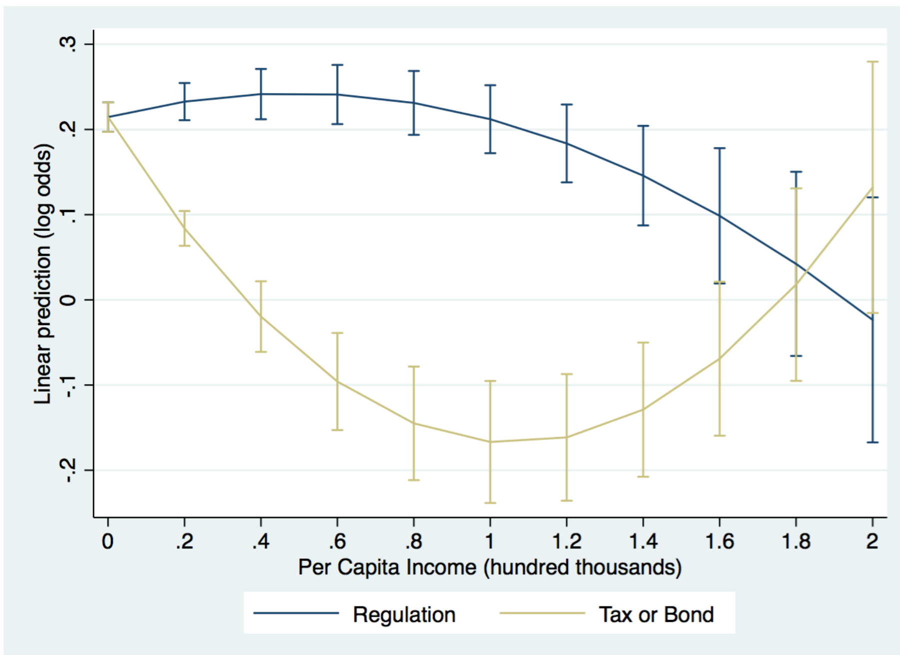


Figure 1.10: Effects of Per Capita Income on Linear Predictions of the Log-Odds of the Share of Votes in Favor of Environmental Propositions, by Proposition Type

occurring around a median household income of $175,000. While the actual turning point is at this high level of income, the convexity of the income-voter support relationship, and thus the effect of diminishing marginal utility of consumption, is apparent well before this point. As shown in Figure 10, the conclusions are unchanged by switching from median household income to block group per capita income. This consistency applies to all subsequent analyses so I report results for median household income only for the remainder of the paper.

Column 3 presents estimation results from the same regression excluding the demographic controls and industry employment shares. The results are very similar in terms of magnitudes and precision, suggesting that the income relationship is not confounded by inclusion of any of the additional covariates. Estimation results are also robust to the use of block group fixed effects in place of census tract fixed effects (Column 4) and the inclusion of county-specific year fixed effects in addition to census tract fixed effects (Column 5) to mitigate the concerns regarding spatial correlation discussed above. Interestingly, in the block group specification the magnitude of the uninteracted income coefficient is notably increased while the others remain similar. For regulatory propositions this suggests a larger and more persistent income effect, while for fiscal propositions this counteracts the negative coefficient on income interacted with the fiscal dummy. The overall effect is to lower the turning point in the income-voter support relationship.

Although the signs and significance are easy to interpret in the log-odds specification, the magnitude of the effects is made clearer by an estimation approach that avoids transformation of the dependent variable. Interpreting the magnitudes of the coefficients in the log transformed linear model in terms of the share of votes in favor requires further distributional assumptions (Papke and Wooldridge, 1996). Column 6 of Table 2 reports estimates from a simple linear regression of the share of votes in favor of environmental propositions, which is acceptable in this case since a negligible number of observations have the dependent variable equal to zero or one. The qualitative results are unchanged, and the turning point in the income-voter support relationship remains near $175,000 for fiscal propositions. The difference in the share of votes in favor between zero median household income and the minimum at $175,000 is nearly 0.05, so differences in block group median household income may account for up to 5% of votes. This is certainly enough to be decisive in close ballot proposition contests.

Since the designation of propositions as pertaining to the environment, and as fiscal or regulatory, is somewhat subjective, there could be concern that some particular mischaracterization is driving the results. To address this issue, I further run the primary specification of the second Column of Table 3 excluding each of the environmental propositions one at a time. In all cases the qualitative results remain and the magnitudes are largely unchanged. Results are also qualitatively unchanged by using wighted least squares with weights proportional to the standard deviation of the outcome variable, $w = (Np(1-p))^{1/2} = (Y*N/(Y+N))^{1/2}$, to correct for heteroskedasticity associated with the grouped nature of the data.

1.4.2 Education Funding

Table 1.4: Voter Support for Public Education Propositions

	odds (1)	odds (2)	odds (3)	odds (4)	odds (5)	odds (6)	share (7)
Median HH Income	-0.123***	-0.152***	-0.156***	-0.322***	-0.099*	-0.164***	-0.156***
	(0.021)	(0.033)	(0.034)	(0.033)	(0.059)	(0.035)	(0.034)
Median HH Income^2	0.027***	0.046***	0.048***	0.094***	0.071*	0.051*	0.048***
	(0.008)	(0.015)	(0.016)	(0.017)	(0.037)	(0.016)	(0.016)
All Schools × Income		0.007					
		(0.006)					
All Schools × Income^2		-0.004*					
		(0.002)					
Non-Rel Schls × Income			0.023	0.036*	0.048	0.026*	0.023
			(0.014)	(0.019)	(0.029)	(0.014)	(0.014)
Non-Rel Schls × Income^2			-0.018**	-0.023**	-0.059***	-0.016**	-0.018**
			(0.007)	(0.009)	(0.016)	(0.007)	(0.007)
Religious Schls × Income			-0.006	-0.013	-0.035	-0.007	-0.006
			(0.016)	(0.023)	(0.024)	(0.015)	(0.016)
Religious Schls × Income^2			0.006	0.009	0.034***	0.005	0.006
			(0.006)	(0.008)	(0.010)	(0.006)	(0.006)
Demographic Controls	Yes	Yes	Yes	No	Yes	Yes	Yes
Fixed Effects	Tract	Tract	Tract	Tract	Blk Grp	Tract& Cnty-Yr	Tract
Observations	152,763	152,763	152,763	152,813	152,763	152,763	152,763

Columns 1 through 6 present estimates from linear regressions of the log-odds of the share of votes in favor, Column 7 from a linear regression of the share itself. Columns 2-7 also include appropriate main effects. Standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

All propositions regarding funding for public education involve income tax increases, general funding requirements, or bonds. Estimation of equation (5) for public education propositions can thus be seen as a further test of the simple relationship between income and demand for publicly provided goods with fiscal implications. As the first Column of Table 4 shows, there is evidence of the same convex relationship found in the context of fiscal environmental propositions. The relationship is again significant at the 1% level but the minimum level of support, or equally the turning point in the income-voter support relationship, occurs at a block group median household income of approximately $225,000. This turning point is close to the upper bound of the support of my sample so in the context of public education funding, voter support is essentially monotonically decreasing in income, although at a decreasing rate.

Coefficients on other demographic characteristics are again intuitive and consistent with the prior literature and omitted from the table. More maledominated and older block groups are less likely to support public education. The coefficients on shares of residents with college education and shares of households with children under the age of 18 are both positive and strongly significant. Household ownership is also strongly positively correlated with education voting outcomes, perhaps indicating that home owners have more incentive to invest in the long term quality of their economy (Harris et al., 2001). Neighborhoods with high shares of racial minorities tend to be less likely to vote in favor of public education ballot propositions, which is a relatively consistent finding in the local expenditure literature (Alesina et al., 1999). It is unclear how theories regarding ethnic fragmentation apply in the case of local racial heterogeneity and a statewide public good, but perhaps voters' perceptions are unduly influenced by their immediate community. This would be an interesting avenue for future research.

To test the hypothesis that private substitutes decrease demand for publicly provided goods among wealthier households, I next estimate equation (7) which includes interactions of income terms with the measure of private substitute availability. Column 2 of Table 4 considers all private schools together and results are similar to the previous regression estimates. It is likely, however, that religious and non-religious private schools substitute for public schools in different ways. Most obviously public schools are non-sectarian, but religious private school tuition also tends to be significantly lower than tuition at non-religious private schools. In 2008, average catholic or other religious private school tuition was between \$5,000 and \$7,000, whereas average non-religious private school tuition was approximately \$16,000 (National Center for Education Statitics, 2010). In terms of the conceptual framework of section 2, non-religious private schools may be a better representation of a more expensive private substitute for publicly provided education quality, whereas religious private schools are a separate alternative involving other characteristics besides quality and price. Certainly given the tuition cost difference, we would not expect income to feature as prominently in the decision to substitute for public education with a religious private school.

Column 3 presents estimation results from including the two types of private schools separately, and indeed there is a significant difference between them. While the coefficients on the interaction of the availability of religious schools with income and its square are close to zero and insignificant, there is a significant negative coefficient on the interaction between income squared and the availability of non-religious private schools. Precisely as suggested by equations (2) and (3), the availability of a more costly private substitute of perceived higher quality reduces voter support for public provision in wealthier neighborhoods.

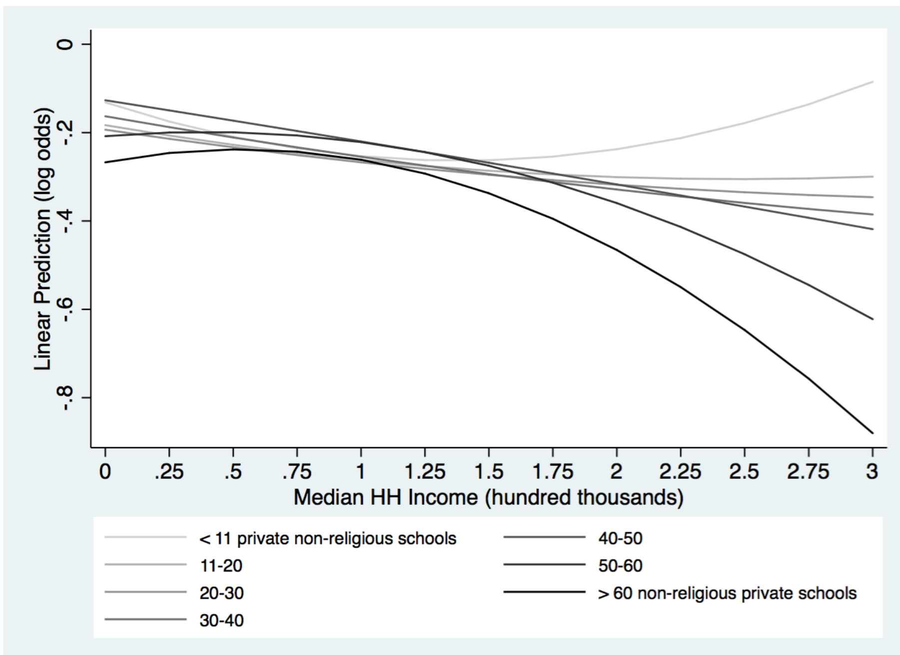


Figure 1.11: Effects of Income on Linear Predictions of the Log-Odds of the Share of Votes in Favor of Environmental Propositions, by Private Substitute Availability

Figure 11 illustrates the effect of private substitute availability on the income-support relationship. I rerun the regression of Column 3 with non-religious private school density binned into intervals and predict log-odds for each interval at the means of all other covariates across the income distribution. The familiar U-shaped relationship is apparent when very few non-religious private schools are available, with a minimum at a median household income of approximately $130,000. At over 30 non-religious private schools in the 5 mile buffer, the log-odds of the share of votes in favor of public education is monotonically decreasing in income, indeed suggesting that as block group residents become wealthier, more substitute towards private schools. At over 50 nearby private schools, the relationship between income and voter support is monotonically negative and concave, indicating that the rate of substitution increases as the availability of the private substitute increases.

These findings are qualitatively robust to the exclusion of other demographic controls (Column 4), switching to block group fixed effects in place of census tract fixed effects (Column 5), and including county-time fixed effects in addition to census tract dummies (Column 6). Interestingly, the relative magnitudes of the coefficients do shift somewhat with these changes in specification. The coefficients are all significantly larger in magnitude when demographic controls are excluded. The uninteracted income coefficients are smaller when block group fixed effects are used, while the size and significance of the coefficient on the interaction of income squared with the count of non-religious private schools notably increase. Moreover, I find a positive coefficient on the interaction of income squared with the count of religious schools, significant at the 5% level. The intuition for this finding is unclear but it is possible that there are competition effects between religious and non-religious private schools driving the result.

Again to facilitate interpretation of the coefficients in terms of actual voting outcomes, the primary specification is also run with the simple share of votes in favor as the dependent variable. The qualitative results remain, as reported in Column (7), although the minimum predicted share occurs at a block group median household income close to $80,000 at the mean level of religious school availability when no non-religious private schools are located in the five mile buffer. The difference in predicted share at zero median income and this minimum is slightly over 0.1, indicating that voter support may differ by as much as 10% between the poorest neighborhoods and those near the turning point.

The findings are also robust to exclusion of any single proposition at a time, as with the environmental voting results, so the conclusion is not sensitive to any particular mischaracterization. Likewise, the use of regression weights to correct for heteroskedasticity does not change conclusions.

1.4.3 Fiscal Proposition Types

The foregoing characterization of ballot propositions as regulatory or fiscal is very coarse, and in particular assumes that voters perceive bonds, income tax increases, and general funding requirements as having the same effect on their tax burden. A frequent criticism of bond propositions, however, is that voters do not understand that they necessitate future tax increases or spending cuts. The assumption that voters respond to bonds and tax increases in the same way thus needs to be explored[5].

[5] A further difference between bonds and explicit tax increases is that bonds are associated with future fiscal consequences. It would be interesting to consider the timing of bond repayments specified in propositions and assess the implied discount rate by comparing voter support for taxes and bonds, as well as the actual magnitudes of the bonds and tax increases, but unfortunately there is not enough variation in the current sample to do so here.

Table 1.5: Voter Support for All Public Good Propositions

	(1)	(2)	(3)
Median HH Income	-0.047**	0.294***	0.305***
	(0.022)	(0.050)	(0.101)
Median HH Income^2	0.001	-0.075***	-0.081***
	(0.009)	(0.020)	(0.020)
Fiscal × Income		-0.537***	
		(0.060)	
Fiscal × Income^2		0.131***	
		(0.025)	
Tax Increase × Income			-0.687***
			(0.077)
Tax Increase × Income^2			0.208***
			(0.034)
Bond × Income			-0.973***
			(0.103)
Bond × Income^2			0.224***
			(0.037)
General Fund × Income			-0.057
			(0.155)
General Fund × Income^2			-0.055
			(0.048)
Observations	590,924	590,924	590,924

Linear regressions of the log-odds of the share of votes in favor. All columns include tract fixed effects and the full set of controls. Standard errors clustered at the county level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Unfortunately the sample of environmental propositions alone, or public education propositions alone, is not large enough or varied enough to conduct the previous analyses separating out different fiscal proposition types. However, the conceptual framework and the underlying intuition apply equally to all propositions regarding publicly provided goods, so I estimate the income voter support relationship across all public good propositions in the sample. As shown in Table 1, these include environment and education propositions, as well as a number pertaining to public transportation and public health and safety. For comparison with the first Columns of Tables 3 and 4, the first Column of Table 5 reports results from the simple regression of voter support on income and its square. Similar to the environmental proposition regression that includes a mixture of regulatory and fiscal propositions, there is some evidence of a negative relationship between income and voter support on average.

Column 2 estimates a separate income effect for regulatory and fiscal propositions across all public good propositions. The coefficient on income alone is positive and significant, as in the equivalent environmental and education regressions. The coefficient on income squared, however, is significantly negative, indicating that very wealthy block groups are less likely to vote in favor of regulatory propositions. This result is somewhat surprising but is perhaps due to omitted private substitution effects. Publicly provided health and transportation are likely more easily substituted by private amenities than environmental quality, possibly explaining why the coefficient is significant here but not in the environmental regression. I find the same strongly significant, convex relationship for fiscal propositions pertaining to all public good propositions that I find for environmental and education propositions with fiscal implications on their own.

Separating out different fiscal proposition types, the coefficients on uninteracted income and its square remain positive and negative respectively, and both significant at the 1% level. The U-shaped relationship between income and voter support is observed for both explicit income tax increases and bond acts, and their coefficients are not significantly different from one another at the 5% level. There is no significant difference, however, between regulatory propositions and funding requirements that make a claim on the state or local general fund without specific compensation. This may be due to sample size limitations, or it may suggest that voters understand there to be fiscal consequences of bonds and tax increases, but they perceive less of an impact of funding requirements.

To better illustrate these results, Figure 12 plots the predicted log-odds of the share of votes in favor of public good propositions over income for each of the four propositions types considered. The income-voter support relationship is concave for both regulatory propositions and those that call for funding requirements, with the share of votes in favor initially increasing in income. The relationship is convex for both bonds and explicit income tax increases, with the share of votes in favor initially decreasing in income. For both bonds and tax increases, the marginal effect of income switches from negative to positive, again consistent with a low relative tax burden among lower income households and a low marginal utility of wealth among richer households. Interestingly, for tax increases the turning point, and equivalently the minimum level of voter support, occurs at a block group median household

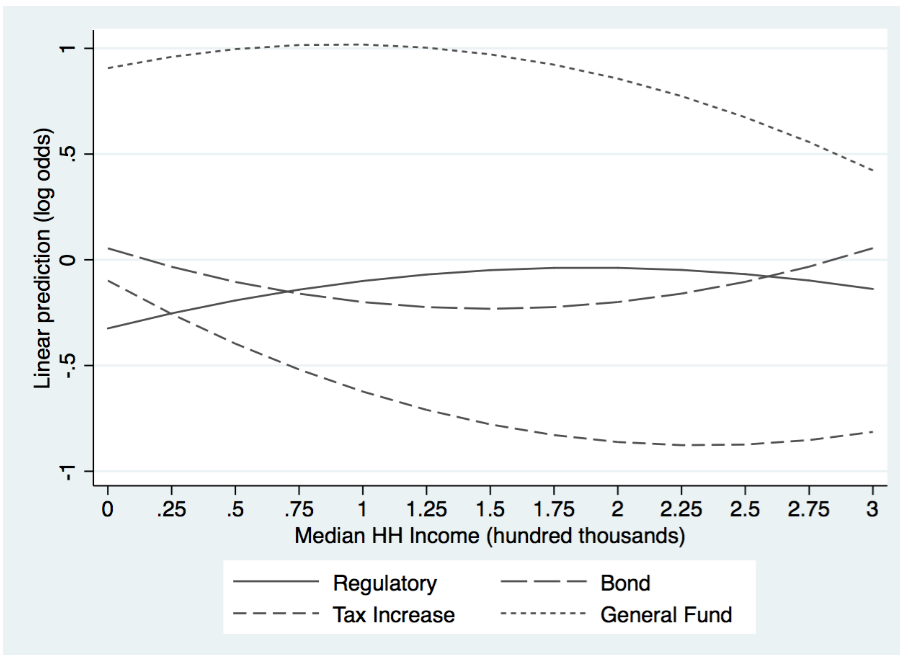


Figure 1.12: Effects of Income on Linear Predictions of the Log-Odds of the Share of Votes in Favor of Public Good Propositions, by Proposition Type

income of $250,000, close to the maximum of the sample, whereas for bonds the turning point is much lower at $150,000. This comparison suggests that progressive taxation and the increasing tax burden associated with higher income is indeed more salient for income tax increases than for bonds, as we might expect.

1.4.4 Voter Turnout and Relocation

Aggregate ballot proposition voting outcomes, and their relationship to demographic and economic characteristics, are of interest in themselves to provide insight into how neighborhoods may vote on future initiatives and referendums. In this case, voter turnout is part of the outcome of interest and factors into voter support for public goods provision. If the objective is to draw conclusions about the nature of demand for public goods and its relationship to income though, then voter turnout is a potentially confounding factor. If low income voters are less likely to vote, for example, and it is only the higher income voters within each block group that participate in the election, then the previously estimated coefficients would be biased indicators of the underlying impact of income on demand for publicly provided goods.

In this case, voter turnout is akin to a sample selection issue since voting on a particular state proposition is unlikely to drive the decision to vote in the election as a whole. Voters are drawn to turnout by presidential and gubernatorial contests, congressional races, as well as local election issues including candidates for office and a set of local ballot propositions. Moreover, conditional on participation in an election, abstention on particular ballot propositions is very low, with an average 93% of active voters within a block group voting on the propositions in my sample. The decision to vote on a proposition and the decision to vote yes or no are separate and unlikely to be related. I thus modify my approach to include proposition-specific turnout itself, similar to the inclusion of the predicted probability of participation in a two stage Heckman selection model (Heckman, 1979). Percentage turnout can be thought of as the probability that the assumed representative voter participates in voting for the proposition.

In prior studies of voter turnout, institutional features and election-specific characteristics have been found to be the most robust correlates, although there is some evidence that age and education are significant predictors of participation at the individual level (Blais, 2006). The relationship between income and voter turnout remains unclear. In terms of proposition voting, Kotchen and Powers (2006) test for bias associated with voter turnout in their analysis of the appearance of open-space referenda in New Jersey but find no effects. Brunner et al. (2011) examine the effect of turnout on conservative voting on redistributive ballot measures and conclude that it does not drive their results.

Table 6 presents results from the analysis of turnout in my sample. To ensure that the inclusion of voter turnout in the proposition regressions will not confound the income estimates, the first Column simply regresses the percent of a block group's voting age population that votes on each proposition on income and fixed effects. Income is not a significant predictor of voter turnout, and the point estimates are close to zero. Including the other control variables in the regression does not change this result.

Columns 2 and 3 present estimation results from rerunning the primary environment and education specifications respectively, including percentage turnout in the regressions. In neither case is the estimated coefficient significant, although the point estimate is negative in both cases and fairly large in magnitude for the public education regression. More importantly, the inclusion of voter turnout changes little about the prior conclusions regarding the relationship between income and voter support. For environmental propositions, the estimates on income, income squared, and their interaction with the dummy for fiscal propositions are virtually unchanged from those reported in the second Column of Table 3. The same is true for propositions regarding public education, comparing the third Column with its equivalent Column 3 of Table 4. Overall there is no evidence that voter turnout is driving results or introducing bias into the estimated income coefficients.

1.4.5 Political Ideology

A further potential concern about the primary results is the extent to which political ideology and voting along party lines is a factor in determining voter support. It may be the case that income is correlated with party affiliation and voters simply vote in a manner consistent with their overall ideology. Prior research has suggested that voting decisions are often made so as to be consistent with a single ideological identity and that voters can pick up partisan cues even on ballot propositions (Branton, 2003). Public goods provision can be understood as a form of redistribution in kind, particularly when associated with fiscal measures, and redistribution is certainly favored by more left-leaning parties. Again, to the extent that we care about actual voting outcomes on public good propositions, it does not matter whether the income-voter support relationship goes through this channel or not. However, leaving party affiliation out of the estimation may lead to biased conclusions about the underlying relationship between income and demand for publicly provided goods.

Table 1.6: Voter Support with Block Group-Proposition Voter Turnout Rate

	(1) % Turnout	(2) Environment	(3) Education
% Turnout		-0.046 (0.060)	-0.109 (0.067)
Median HH Income	0.002 (0.012)	0.091* (0.053)	-0.150*** (0.033)
Median HH Income^2	-0.004 (0.004)	-0.039 (0.027)	0.046*** (0.016)
Fiscal × Income		-0.350*** (0.070)	
Fiscal × Income^2		0.116*** (0.034)	
Non-Rel Schls × Income			0.022 (0.014)
Non-Rel Schls × Income^2			-0.017** (0.007)
Religious Schls × Income			-0.006 (0.015)
Religious Schls × Income^2			0.006 (0.006)
Demographic Controls	No	Yes	Yes
Industry Controls	No	Yes	No
Observations	131,185	241,330	152,763

Column 1 is a linear regression of the percent of a block group's population voting on a proposition. Columns 2 and 3 are linear regressions of the log-odds of the share of votes in favor. All regressions include proposition and census tract fixed effects. Standard errors are clustered at the county level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Similar to the analysis of voter turnout, I first assess the extent to which political ideology is correlated with the variable of interest, using the percent of a block group's vote that goes to a right-wing presidential or gubernatorial candidate. This variable is thus block-group and election specific but does not vary across propositions all appearing on the same ballot. As the first Column of Table 7 reports, income and party affiliation are strongly significantly related within my sample, with the percent voting for a right-wing candidate first increasing and then decreasing in income. The turning point occurs at over $200,000, so conservative voting is more or less monotonically increasing, although convex, in income after controlling for block group and election fixed effects. This finding is consistent with prior evidence, which shows that in the U.S., income is positively related to republican party affiliation until very high levels of income are reached (Kohut et al., 2009).

Column 2 of Table 7 adds this measure of political ideology as an additional covariate in the primary specification for environmental propositions. The percent voting for a right-wing political candidate is indeed strongly significantly associated with voting against such propositions, as may be expected. However even after controlling for this channel, I still find evidence of the same previously observed convex relationship between income and voter support. For regulatory propositions, the correlation between income and the share of votes in favor actually becomes more significant. For fiscal propositions, very wealthy and very poor neighborhoods remain most supportive of environmental propositions, while block groups with median household income near $150,000 are least supportive.

Party affiliation is also a strongly significant predictor of voting in favor of public education propositions, as reported in the final Column of Table 7. Again as expected, the greater the percentage of a block group's population voting for a conservative candidate, the less support there is for education-related propositions. The correlation between right-wing candidate voting and support for public education funding is indeed even stronger than that for environmental propositions. Yet again the coefficients on income and its interactions remain qualitatively similar to previous results. There is a clear convex relationship between income and support for education propositions, significant at the 1% level, but the positive effect of very high income diminishes in the presence of increased private school availability. The magnitude of the income relationship is somewhat reduced when political affiliation is included in the regressions though, suggesting that ideological identity may have driven a portion of the previously discussed result.

Table 1.7: Voter Support with Block Group Party Affiliation

	(1) % Right	(2) Environment	(3) Education
% Voting Right-Wing		-1.278***	-1.737***
		(0.110)	(0.231)
Median HH Income	0.064***	0.126***	-0.079***
	(0.008)	(0.043)	(0.026)
Median HH Income^2	-0.015***	-0.047**	0.032***
	(0.003)	(0.023)	(0.011)
Fiscal × Income		-0.340***	
		(0.060)	
Fiscal × Income^2		0.113***	
		(0.029)	
Non-Rel Schls × Income			0.019
			(0.015)
Non-Rel Schls × Income^2			-0.020***
			(0.006)
Religious Schls × Income			-0.018
			(0.015)
Religious Schls × Income^2			0.013**
			(0.005)
Demographic Controls	No	Yes	Yes
Industry Controls	No	Yes	No
Observations	131,185	241,330	152,763

Column 1 is a linear regression of the percent of a block group's votes cast for a right-wing candidate. Columns 2 and 3 are linear regressions of the log-odds of the share of votes in favor. All regressions include proposition and census tract fixed effects. Standard errors are clustered at the county level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

1.5 Conclusion

Voting on initiatives and referendums is a widely used process for legislative decision-making on a range of issues, often focusing on the public provision of goods and services. Proposition voting outcomes offer an advantageous but relatively under-utilized approach to studying the nature of demand for such amenities, including environmental quality and funding for education. In this paper, I use statewide California ballot propositions on environmental protection, public education, and public goods provision generally, to characterize the relationship between income and demand for publicly provided goods.

I find evidence that income is certainly a strong predictor of voter support for certain public goods propositions, but that the relationship is complex. In particular, the effect of income on voter support depends on whether a proposition is regulatory in nature or has fiscal consequences. For the latter, there is a strongly significant and robust convex relationship between income and voter support, suggesting that middle class neighborhoods, where households are likely to have both relatively high tax burdens and marginal utilities of wealth, are least likely to approve such measures. The income-voter support relationship is further complicated by the availability of private substitutes for the publicly provided good. I find evidence that a larger number of private schools near a neighborhood depresses the marginal positive effect of income on support for public education funding among wealthier households.

Broadly speaking, these results provide insight into the likelihood that different types of propositions will be successful in different communities. Moreover, they demonstrate that the effect of income growth on voter support for fiscal propositions in particular may not be uniformly positive or negative across communities. Demand for public provision also varies with households' ability to substitute privately, at least in the context of public education. As access to private substitutes increases in conjunction with income growth, support for pubic provision may decrease, thus leading to greater inequality in provision of amenities or quality between wealthy and poor households.

2 Willingness to Pay vs. Willingness to Vote: Consumer and Voter Avoidance of Controversial Technologies

2.1 Introduction

Many consumer goods are produced using controversial technologies that receive mixed acceptance from the general public due to the negative consequences or risks they impose. The food industry has generated a particularly large number of these controversies, with examples ranging from irradiation to the use of artificial growth hormone in milk production (Lusk et al., 2014). The public's concerns often regard private health risks associated with consumption, but may also regard environmental or social externalities, as demonstrated by consumers' willingness to pay (WTP) for green or ethical goods, such as dolphin-safe tuna (Teisl et al., 2002) and fair trade coffee (Loureiro and Lotade, 2005), that offer no private benefits. Genetically modified (GM) food is undoubtedly one of the most controversial technologies at present, with many individuals and media outlets expressing concern about both consumption safety and environmental risks, despite the lack of scientific evidence validating such fears (Moschini, 2008). The extent of misinformation and lack of knowledge regarding agricultural biotechnology fuels the controversy and results in tremendous heterogeneity of preferences, making it a particularly interesting topic of study.

As with many controversial technologies, individuals can express their aversion to GM food both in the marketplace and at the ballot box. On the one hand, consumers can opt to pay a premium for food free from GM ingredients. A large literature has sought to estimate consumer WTP for GM-free food, along with its demographic and contextual determinants (see Lusk et al. (2005) and Costa-Font et al. (2008) for summaries). On the other hand, individuals as voters can decide to support more stringent regulation of GM technology. Mandatory labeling of GM foods has become a contentious ongoing debate, with citizens in numerous US states voting on ballot initiatives calling for the regulation. A number of studies have sought to understand the conditions under which mandatory labeling may be efficient, and to highlight its potential consequences (for example Fulton and Giannakas (2004), Roe and Sheldon (2007), and Bonroy and Constantatos (2014)). A ban on all or certain GM foods would be a more drastic regulatory option that has been enacted in several countries around the world (Gruère and Rao, 2007, Qaim, 2009).

The fact that people currently face real choices on GM food as both consumers and voters provides a unique opportunity to compare how a given individual makes decisions in both roles regarding precisely the same good. A long strand of theoretical literature considers whether people behave differently, and may perhaps have different preferences, depending on the role in which they are acting (Hausman and McPherson, 2006). Nyborg (2000) expounds on this idea specifically in the context of environmental valuation. Indeed this consideration has been used to critique environmental valuation methods that confound the two decision-making contexts (Blamey et al., 1995, Sagoff, 2007), as well as studies that infer policy preferences from consumer-based evidence (Hamilton et al., 2003). Empirical comparisons of voter and consumer choices are more rare, given the infrequency with which consumers and voters actually face the same issue. In this paper, I compare willingness to pay a premium for a product that avoids a controversial technology, willingness to vote in favor of mandatory labeling of goods produced with it, and willingness to vote for an outright ban. I consider how different factors, in particular income and perceptions of the technology, affect these decisions differentially.

A handful of papers have undertaken a similar comparison, beginning with Hamilton et al. (2003) which uses a survey to assess the relationship between WTP for pesticide-free food and voter support for a ban on pesticides. The authors find that WTP certainly factors into an individual's voting decision, but that consumer behavior on its own is not a strong predictor of voting decisions. They explain that an individual with zero WTP may still vote in favor of regulation according to free-rider rationale, but that conversely high option value may induce an individual with high WTP to vote against regulation. Brooks and Lusk (2012) conduct a survey on individual preferences regarding products derived from cloned animals and find much greater voter support than would be suggested by their estimates of consumer WTP. Similarly Alphonce et al. (2014) find much stronger preferences for food safety among voters than consumers in their survey regarding restaurant standards. This paper is the first to address the issue of differing consumer and voter preferences in the context of GM foods. It also improves on the prior literature through use of an actual contemporaneous referendum vote to frame the empirical study, by assessing the factors that may lead to a divergence between WTP and voting support both theoretically and empirically, and by considering multiple regulatory options that enable us to isolate considerations of free riding and option value.

In a related vein and in the context of GM food, Carlsson et al. (2007) conduct a survey of Swedish consumers, comparing WTP for GM-free food under mandatory labeling and a ban with the aim of distinguishing between the private good and public good motivations underlying their choices. They find that WTP is not significantly higher under the ban after controlling for private benefits and conclude that there is no welfare argument for a ban. Loureiro and Hine (2004) instead compare voluntary and mandatory labeling using a standard contingent valuation survey of Colorado shoppers. They find that respondents report higher WTP for mandatory labeling compared to voluntary labeling, but conclude that mean WTP for mandatory labeling is less than would be required to cover the costs of such a policy. However both of these papers are subject to the aforementioned issue of using individual consumer-oriented preferences to make policy inferences. In this paper, I elicit WTP for GM-free food in a consumer context, for comparison with intended vote on an upcoming referendum on mandatory labeling of GM foods.

I first present a straightforward utility maximization framework to formalize the intuition regarding the relationship between WTP and voting decisions, assuming each individual has a single utility function underlying their consumer and voter decisions. The framework shows that WTP is of course not a perfect predictor of willingness to vote, as a single consumer who buys a good produced using a controversial technology makes only a marginal contribution to its associated risks or externalities. A vote in favor of regulation, however, marginally increases the probability that those risks or externalities will be limited. In addition, as discussed in Hamilton et al. (2003), regulation may entail a loss in future consumer choices that the private purchase decision does not. I show instead that WTP is correlated with the probability of voting in favor of regulation, but that the relationship is not smooth. Moreover, WTP divides individuals into categories across which the relationship between voting probabilities and income differs.

The empirical study is based around a 2012 California ballot initiative proposing mandatory labeling of GM food. The initiative would have required all GM food sold in California, up to a certain threshold tolerance and excluding meat, dairy, and food sold in restaurants, to be labeled as such. Congress and several state governments had previously voted against mandatory labeling, but Proposition 37 was the first time the policy was put forward for a popular vote. Shortly before the election I conducted an online survey of 715 California residents, eliciting WTP for food free from GM ingredients as well as intended vote on the mandatory labeling proposition, along with willingness to vote in favor of a hypothetical ban on GM ingredients. Using an actual proposition as context increased respondent familiarity with the issue and meant responses would be more similar to those of an actual vote.

Using the conceptual model to guide my econometric approach, I confirm that WTP depends positively on the perceived private benefits associated with consumption of GM-free food but only weakly positively on income. Surprisingly, I also find that perceived environmental impacts of the technology appear to be a greater motivator of purchasing GM-free food than perceived risks to consumer health. Both the decision to support mandatory labeling and the decision to vote in favor of a ban on GM food depend on WTP. However, I also find that the probability of voting in favor of regulation is either uncorrelated with or decreasing in income, unlike WTP and contrary to the model's predictions. The results also suggest that the role of perceptions regarding the safety of GM food may be different among consumers and voters, with lack of confidence tending to increase voter support for mandatory labeling but decrease WTP and support for a ban.

The following section presents a conceptual model on the determinants of consumer and voter avoidance of controversial technology via voluntary and mandatory labeling and a ban, assuming each individual is subject to a single utility function. Section 3 describes the survey instrument and provides summary statistics of the data collected. Section 4 presents the econometric analysis, motivated by the predictions of Section 2. Section 5 concludes.

2.2 Conceptual Framework

Although WTP for a good produced without use of a controversial technology and willingness to vote for direct regulation are both indicative of aversion to the technology, they are very different decisions. A consumer's individual purchase decision has a trivial impact on the use of the technology whereas a policy change limits it by design. Purchasing a product and changes in regulation also entail very different costs, and individuals as consumers face different constraints than individuals as voters[6]. The following framework provides some intuition on the relationship between WTP and willingness to vote in favor of mandatory labeling and a ban, under the assumption that a given individual has a single utility function underlying both their consumer and voter decisions.

2.2.1 Consumer Behavior

Suppose that an individual can choose between two versions of a product, one produced using a controversial technology and a potentially favored alternative that avoids the technology and the associated perceived externalities or risks.

[6]This analysis is not concerned with the actual costs of going out to vote or of supporting regulation, and instead simply considers preferences for or against particular regulatory changes.

Following Hamilton et al. (2003), I assume a random utility model such that the relevant portion of an individual's utility under regulatory scenario s is

$$U_s = V_s + \epsilon_s = v(X, p_s, r_s, b_s, f_s) + \epsilon_s$$

where X represents a vector of individual specific characteristics including income, p_s is the price of the good including time spent searching for it, r_s represents the perceived private benefits of the chosen good, and b_s the perceived public benefits associated with the overall level of consumption[7]. f_s is consumer freedom of choice, to allow for the possibility of option value, and ϵ_s is randomly distributed with mean zero. Note that b_s depends on the purchasing decisions of all consumers in the market, and indeed I assume that the individual consumer's decision has no effect on b_s. A consumer may, however, gain utility from simply making what she believes to be an ethical choice, akin to the "warm glow" of charitable giving (Andreoni, 1990). I do not include a separate variable to capture this additional utility as its provision is coincident with the provision of private benefits, but note that $\frac{\partial v}{\partial r_s}$ may be a function of b_s.

Consider the representative portion of the consumer's utility under four different regulatory scenarios: no labeling ($s = 0$), voluntary labeling ($s = 1$), mandatory labeling ($s = 2$), and a ban on the controversial good ($s = 3$), e.g. food containing GM ingredients. Normalizing price to 1 in the no labeling scenario and suppressing the X argument we have:

$$V_0 = v(1, r_0, b_0, f_0)$$

where r_0 represents private benefits corresponding to purchase of the controversial good, b_0 represents provision of public benefits when no one purchases the favored alternative, and f_0 denotes consumers' lack of freedom to choose between the two. Under voluntary labeling, an individual's utility is given by:

$$V_1 = max\{v(1, r_0, b_1, f_1), v(1 + \delta_1, r_1, b_1, f_1)\}$$

since she can choose between the controversial and alternative goods. In the case of the former, she faces no increase in price or private benefits relative to scenario 0. In the case of the latter, price increases by δ_1 and private benefits increase to r_1, since I assume the favored alternative is at least as desirable in

[7] I say "perceived" private and public benefits to accommodate the fact that in the case of GM-free food these benefits are largely unsubstantiated and individuals' perceptions of them vary widely across the population.

terms of private characteristics. Under either option, public benefits increase to b_1 since some consumers purchase the alternative, and freedom of choice increases to f_1. Similarly under mandatory labeling:

$$V_2 = max\{v(1 + \Delta_2, r_0, b_2, f_1), v(1 + \Delta_2 + \delta_2, r_1, b_2, f_1)\}$$

where the prices of both the controversial and alternative goods increase by Δ_2, denoting the additional cost burden of mandatory labeling across all products. δ_2 represents the price premium for the favored alternative, which may be small or even negative if mandatory labeling effectively drives the controversial technology out of the market. Lastly under a ban on the controversial technology, individual utility is given by:

$$V_3 = v(1 + \delta_3, r_1, b_3, f_0)$$

where δ_3 represents the increase in price of switching entirely to the favored alternative, and b_3 denotes the corresponding change in the provision of public benefits. Freedom of choice reverts to f_0.

It seems most plausible that the price of the favored good decreases as regulation becomes more stringent, namely that $\delta_3 < \Delta_2 + \delta_2 < \delta_1$, particularly since I include search costs. Given $\Delta_2 > 0$, this further implies $\delta_2 < \delta_1$ as we would expect. Provision of public benefits varies across the three scenarios since it depends on the purchasing decisions of the entire population. As regulation becomes more stringent, the favored alternative becomes relatively less costly and represents an increasingly large market share, up to the extreme of the entire market under scenario 3. As the controversial good represents a progressively smaller share of consumption and production, perceived public benefits increase and we have $b_3 \geq b_2 \geq b_1 \geq b_0$. I also assume the partial derivatives of the utility function have the expected signs, namely $\frac{\partial v}{\partial p_s} < 0$ while all others are at least non-negative.

Assuming consumers are utility-maximizing, willingness to pay under scenarios 1 and 2 are the solutions, δ_1^* and δ_2^* to the following equalities:

$$v(1, r_0, b_1, f_1) = v(1 + \delta_1^*, r_1, b_1, f_1)$$
$$v(1 + \Delta_2, r_0, b_2, f_1) = v(1 + \Delta_2 + \delta_2^*, r_1, b_2, f_1)$$

Replacing both sides of the above equations with linear approximations of

v yields the following expression for WTP:

$$\delta_1^* = \delta_2^* = \delta^* = -\frac{\partial v}{\partial r_s}(r_1 - r_0) / \frac{\partial v}{\partial p_s} \tag{8}$$

WTP thus depends only on the marginal utility associated with the additional private benefits of purchasing the favored alternative good, scaled by the marginal utility of income. Recall that $\frac{\partial v}{\partial r_s}$ may still depend on the consumer's beliefs about the environmental or social impacts of the controversial technology, so WTP may still depend on b. A rational consumer will choose the alternative good in labeling scenario s if and only if $\delta_s < \delta^*$.

2.2.2 Voter Behavior

Let $dV_{s,t}$ represent the change in approximate utility of moving from scenario s to scenario t. A utility-maximizing voter will support a change in regulation from s to t if and only if $dV_{s,t} > 0$. Thus the probability that an individual votes in favor of the new regulation is simply $\Pr(dV_{s,t} > 0)$. First compare voluntary labeling (s=1) to no labeling (s=0), separately for those with WTP above and below the premium for the favored alternative under voluntary labeling. Substituting in the expression for WTP given by equation (1) gives:

$$dV_{0,1}|(\delta^* \leq \delta_1) = \frac{\partial v}{\partial b_s}(b_1 - b_0) + \frac{\partial v}{\partial f_s}(f_1 - f_0) \tag{9}$$

$$dV_{0,1}|(\delta^* > \delta_1) = \frac{\partial v}{\partial p_s}(\delta_1 - \delta^*) + \frac{\partial v}{\partial b_s}(b_1 - b_0) + \frac{\partial v}{\partial f_s}(f_1 - f_0) \tag{10}$$

Equations (2) and (3) are unambiguously positive so all individuals would be in favor of voluntary labeling. Intuitively those with δ^* less than the premium for the favored alternative can buy the conventional good at the original price but still benefit from greater freedom of choice and any public benefits due to other consumers switching. Those with δ^* greater than the premium choose to buy the alternative because it increases their utility, by definition.

To compare voluntary labeling (s=1) to mandatory labeling (s=2), we now must consider three types of individuals: those with $\delta^* \leq \delta_2$ who choose the controversial good in both scenarios, those with $\delta_2 < \delta^* \leq \delta_1$ who switch from the controversial good to the alternative as labeling moves from voluntary to mandatory, and those with $\delta_1 < \delta^*$ who choose the alternative in both scenarios. Again substituting in the expression for WTP:

$$dV_{1,2}|(\delta^* \leq \delta_2) = \frac{\partial v}{\partial p_s}\Delta_2 + \frac{\partial v}{\partial b_s}(b_2 - b_1) \tag{11}$$

$$dV_{1,2}|(\delta_2 < \delta^* \leq \delta_1) = \frac{\partial v}{\partial p_s}(\Delta_2 + \delta_2 - \delta^*) + \frac{\partial v}{\partial b_s}(b_2 - b_1) \tag{12}$$

$$dV_{1,2}|(\delta_1 < \delta^*) = \frac{\partial v}{\partial p_s}(\Delta_2 + \delta_2 - \delta_1) + \frac{\partial v}{\partial b_s}(b_2 - b_1) \tag{13}$$

Equation (4) suggests that among individuals with low or zero WTP, a voter is more likely to favor mandatory labeling if she has a low marginal utility of income (high level of income) and perceives larger public impacts of the controversial technology. In contrast, equation (5) suggests that for individuals with intermediate WTP, the effect of income may be positive or negative but is likely to be small as it depends on the difference between WTP and the price increase they face. Lastly equation (6) shows that all those with high WTP benefit from mandatory labeling, but that the probability of such an individual voting in favor is actually decreasing in income. Intuitively, if an individual is purchasing the favored alternative regardless of the regulatory scenario, she benefits more from a reduction in its price if she is less wealthy. Across all individuals, $\Pr(dV_{1,2} > 0)$ is increasing in perceived public benefits but does not depend on private benefits after controlling for WTP.

To compare a ban to voluntary labeling, we only need consider two types of individuals, those with $\delta^* \leq \delta_1$ who choose the controversial good under voluntary labeling, and those with $\delta^* > \delta_1$ who choose the favored alternative under voluntary labeling. Substituting in for WTP as above:

$$dV_{1,3}|(\delta^* \leq \delta_1) = \frac{\partial v}{\partial p_s}(\delta_3 - \delta^*) + \frac{\partial v}{\partial b_s}(b_3 - b_1) - \frac{\partial v}{\partial f_s}(f_1 - f_0) \tag{14}$$

$$dV_{1,3}|(\delta^* > \delta_1) = \frac{\partial v}{\partial p_s}(\delta_3 - \delta_1) + \frac{\partial v}{\partial b_s}(b_3 - b_1) - \frac{\partial v}{\partial f_s}(f_1 - f_0) \tag{15}$$

Akin to equation (5), equation (7) indicates that for individuals with low or moderate WTP, the sign of the effect of income on the probability of voting in favor a ban depends on WTP itself. Again perceived public benefits of the alternative have a positive effect, but in this case it is counterbalanced by the disutility associated with loss of freedom to choose between the controversial good and its alternative. Equation (8) suggests that all individuals with high WTP should prefer the ban to voluntary labeling regardless of their actual level of WTP, so long as they do not value freedom of choice extremely highly.

Moreover, the probability of a vote in favor is again decreasing in income for those with high WTP, as less wealthy individuals benefit more in terms of utility from a reduction in the price of the alternative if they purchase it regardless of the regulatory scenario.

Note that since the above framework relies exclusively on perceived public and private benefits, not on actual benefits to health or the environment or society in general, I cannot say anything about the welfare implications of each regulatory scenario. The aim of this paper is just to clarify the factors underlying consumer and voter decisions, not to estimate the welfare effects of those decisions. In the case of GM food, individuals make decisions based on the health and environmental risks and damages they perceive to be associated with the technology, whereas the actual health and environmental effects of agricultural biotechnology are a separate matter.

2.3 Survey and Data

The context for the empirical study is a 2012 California ballot initiative (Proposition 37) proposing mandatory labeling of GM food. Had it passed, the initiative would have required all food sold in California containing GM ingredients above a certain threshold tolerance to be labeled as such, excluding meat, dairy, and food sold in restaurants. Although eventually rejected by a slim margin, prior polls had shown voters to be strongly in favor. Figure 1 plots cumulative campaign spending and poll results over the period leading up to the election. It shows a clear shift in the majority opinion following a large increase in spending by the coalition against mandatory labeling. The campaign against the proposition largely concentrated their efforts on communicating the costs that consumers would likely incur if mandatory labeling were implemented(McFadden and Lusk, 2013).

2.3.1 Survey Instrument

The survey was administered online to a stratified sample of 715 California voting-age residents ten days prior to the election. The panel was constructed from surveymonkey.com's pre-registered database of respondents who complete web-based surveys in exchange for small rewards (a \$0.50 charitable donation and entry into a gift card lottery). Although web-based surveying is a comparatively new mode for collecting WTP data, and stated preference data more generally, there is evidence supporting its validity relative to phone and

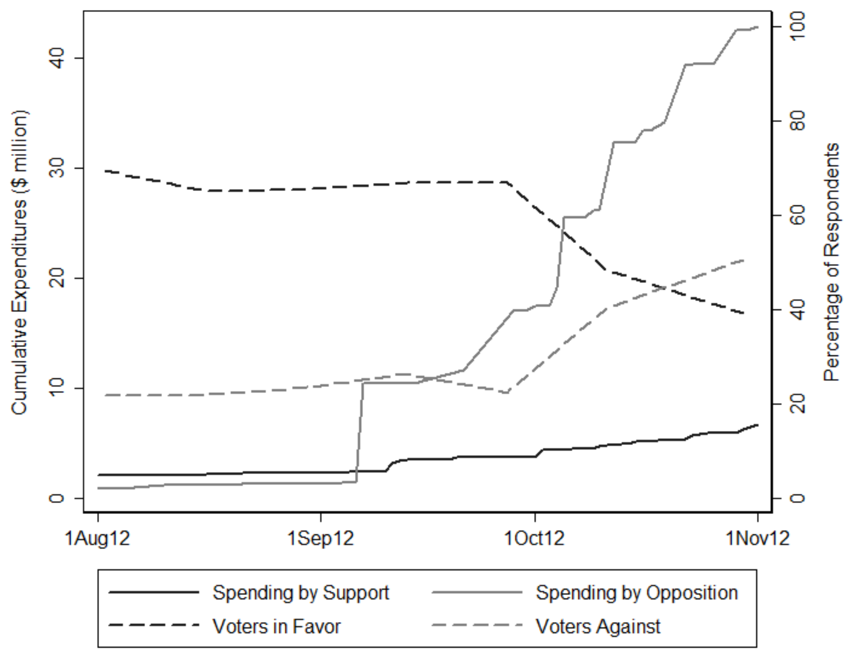


Figure 2.1: Proposition 37 Cumulative Campaign Spending and Pre-Election Poll Results

Sources: California Business Roundtable and Pepperdine University School of Public Policy Initiative Survey; CAL-ACCESS Campaign Finance and Lobbying Activity face-to-face survey modes (Lindhjem and Navrud 2008, Nielsen 2011)[8]. While I attempted to obtain a sample that reasonably represented the CA voting-age population, I was limited by the pool of potential respondents. This sample therefore tends to be older, more educated, wealthier, and less racially diverse than the CA population overall. I nonetheless have enough variation in the sample to control for these characteristics in the analyses.

To elicit WTP for a GM-free product under a mandatory labeling scenario, respondents viewed simultaneous side-by-side images of otherwise identical nutrition and ingredient labels for a popular breakfast cereal, only one of which carried the statement "MAY CONTAIN GENETICALLY ENGINEERED INGREDIENTS". I also included a sentence encouraging respondents to consider their actual household budget when making their choice to help mitigate hypothetical bias. Similar surveys often provide respondents with the additional explanation that a product being unlabeled implies its GM-free status but I omitted such a statement as grocery store shoppers would be left to make this inference for themselves. Respondents gave their WTP for the unlabeled (GM-free) version of the product by selecting the appropriate interval ranging from \$0 to over \$3.00, in addition to the \$2.99 price of the labeled product, or opted out by stating that they would purchase neither product. Although a preferable value for the purpose of this analysis would be an estimate of consumers' willingness to pay for GM-free food overall, I posed the question in reference to a single product to better recreate consumers' actual grocery purchase decisions. Obtaining estimates of overall WTP is further complicated by the fact that WTP for GM-free food varies depending on the type of product in question (Rousu et al., 2007) and characteristics conferred by genetic engineering(Colson and Huffman, 2011).

Following the WTP question, respondents answered how they intended to vote on Proposition 37 and how they would vote in favor of a ban on GM ingredients in food. Randomization of question order was unfortunately infeasible for this survey. For the question regarding the mandatory labeling initiative, I included the description of the proposition that appeared on the actual ballot when citizens went to vote. This is in contrast to standard CV methodology, where provision of background information is an important

[8]Moreover, the aim of this paper is not to accurately estimate average WTP or the proposition's approval rate but rather to compare consumer and voter decisions. Bias associated with the use of an online survey is therefore not a concern unless it affects consumption and voting decisions differentially. Nonetheless, estimates for WTP from this survey fall within the range found in the literature, which includes a number of experimental studies. The approval rating for Proposition 37 was also similar to estimates provided by pre-election polls at the time I conducted the survey.

component of survey design (Vossler and Kerkvliet, 2003, Johnston, 2006). As before, I omitted any such information to better capture likely voter behavior, rather than attempt to estimate the value of a public good to a fully informed population. Additionally, given the extent of recent media campaigning, most members of the public were already aware of GM food and the ballot initiative and had formed opinions on the issue.

In addition to standard demographic data, I also collected basic information on respondent's knowledge and perceptions of GM food. Respondents provided a self-reported measure of how much they knew about the use of genetic engineering in food production on a scale of 1 (none) to 5 (very well-informed), similar to the subjective measure of prior information in Huffman et al. (2007). As a more objective measure of GM knowledge, respondents also provided the percentage of packaged grocery store food they thought contained GM ingredients. To proxy for perceived private and public benefits of GM-free food, respondents also rated how safe they thought GM food was for the environment and for consumption on scales of 1 (very unsafe) to 5 (very safe), or stated that they were unsure or did not know.

2.3.2 Summary Statistics

Of the 715 respondents, 7% opted out of the WTP question and 55% reported 0 WTP for the GM-free product. Using the midpoints of the WTP ranges in the data, mean WTP was \$0.34 or 11% of the base price for the full sample and \$0.85 or 28% of the base price for respondents with WTP>0. These estimates fall within the wide range of estimates in the literature, toward the more conservative end of the spectrum. 29% of respondents scored themselves 1 or 2 out of 5 in terms of how much they knew about genetically engineered food, whereas 42% scored themselves 4 or 5 out of 5. However, 68% believed that the percentage of non-organic packaged food items at a regular U.S. grocery store that contain GM ingredients was between 0 and 60%. The true proportion is over 70% (Grocery Manufacturer's Association, 2013). 33% of respondents believed GM foods to be fairly or very unsafe for consumption while 45% believed them to be fairly or very safe. The remainder were uncertain or did not know. 43% believed that growing GM crops was unsafe for the environment, while 36% believed it to be safe.

Table 1 describes and counts the number of survey respondents falling within each categorization defined by WTP, support for mandatory labeling, and support for a ban. I consider three categories of WTP to coarsely approximate the division suggested by the conceptual framework: zero, moderate (\$0.01 to \$0.75), and high (more than \$0.75). This categorization is admit-

Table 2.1: Characteristics of Respondent Types

Respondent Category	N	%	Age	Education	Income	Self-Rep Knowledge	Test Fail	Health Safety	Environ Safety
Not Ban or Label									
Zero WTP	213	87	54.31	15.84	53.05	3.31	0.42	4.34	4.16
Low WTP	24	10	52.88	15.67	48.44	2.92	0.42	3.81	3.50
High WTP	8	3	50.63	16.88	42.58	3.38	0.50	4.29	4.00
All	245	100	54.04	15.85	52.25	3.27	0.42	4.29	4.09
Label Only									
Zero WTP	69	55	48.30	15.84	44.75	2.85	0.39	3.86	3.63
Low WTP	29	23	48.38	16.28	55.03	2.76	0.34	3.42	3.13
High WTP	27	2	41.59	16.11	50.17	3.30	0.30	3.30	2.74
All	125	100	46.87	16.00	48.30	2.93	0.36	3.64	3.32
Ban and Label									
Zero WTP	97	36	49.92	15.21	43.22	3.15	0.31	2.16	1.87
Low WTP	84	31	44.49	15.29	37.23	3.20	0.35	2.48	1.93
High WTP	87	32	41.90	15.51	43.16	3.48	0.25	2.16	1.84
All	268	100	45.61	15.33	41.32	3.28	0.30	2.26	1.88
Ban Only									
Zero WTP	17	71	51.18	15.00	42.63	2.71	0.41	2.56	3.25
Low WTP	2	8	55.00	15.00	43.75	3.50	0.50	4.00	3.00
High WTP	5	2	39.80	14.80	51.25	1.60	0.20	2.00	1.67
All	24	100	49.13	14.96	44.52	2.54	0.38	2.56	2.90
Opt Out	53		48.47	16.13	52.82	3.29	0.28	2.02	1.84
All	715		49.05	15.67	47.25	3.19	0.36	3.19	2.92

Note: Self-Reported Knowledge is the score respondents gave themselves in terms of how much they knew about GM food, between 1 (nothing) and 5 (a lot). Test Fail is an indicator variable denoting that the respondent incorrectly stated the prevalence of GM-foods in typical supermarkets. Health safety and environmental safety range from 1 (very unsafe) to 5 (very safe).

tedly arbitrary but subsequent results are not sensitive to the particular cutoff values. Overall, the observable patterns make intuitive sense. Respondents against both banning and labeling tend to be older, consistent with the previous literature discussed in the introduction. Those who are against both banning and labeling, or are in favor of both, report being better informed about GM-food than those in favor of one policy but not the other. However the percentage failing the objective test about GM-food decreases as we move to respondents choosing stricter regulation. Across all respondent types, individuals tend to be slightly more concerned about the environmental impacts of growing genetically engineered crops than about the health impacts of consuming GM food (a lower safety score indicates greater concern). Respondents favoring stricter regulation also appear more concerned about both environmental and consumer safety.

The largest respondent category is zero WTP and against both banning and mandatory labeling. These individuals tend to be older and wealthier than the full sample and very confident in the safety of GM foods. A significant proportion of respondents with zero WTP are willing to require labeling but are not in favor of a ban. They tend to be younger and less wealthy than those against both policies with zero WTP, feel less well-informed, and be more concerned about both health and environmental safety. Those in favor of both banning and mandatory labeling are approximately equally likely to have zero, moderate, or high WTP. Regardless of WTP, these respondents unsurprisingly tend to report being very concerned about the health and environmental safety of GM food. The 24 respondents in favor of a ban but not mandatory labeling are somewhat difficult to explain, as intuitively labeling is a more moderate regulatory option than a ban. Given the small size of this subsample, their counterintuitive choice patterns may just be due to idiosyncratic aversion toward proposition 37, or mandatory labeling as a regulatory option.

Figure 2 presents a histogram of WTP by willingness to vote in favor of mandatory labeling, showing that the distribution of WTP is indeed much more concentrated at 0 among respondents who would vote against the ban than among those who would vote in favor. Intuitively those who are not opposed to the technology would be neither willing to pay to avoid it nor willing to vote against it. Figure 3 presents the frequency of household income per household adult by willingness to vote for mandatory labeling. The distribution of income is more right-skewed among individuals who would vote in favor than among those who would vote against. Low income individuals thus appear more likely to vote for regulation than higher income individuals. I explore this finding in the analysis below. Equivalent histograms examining

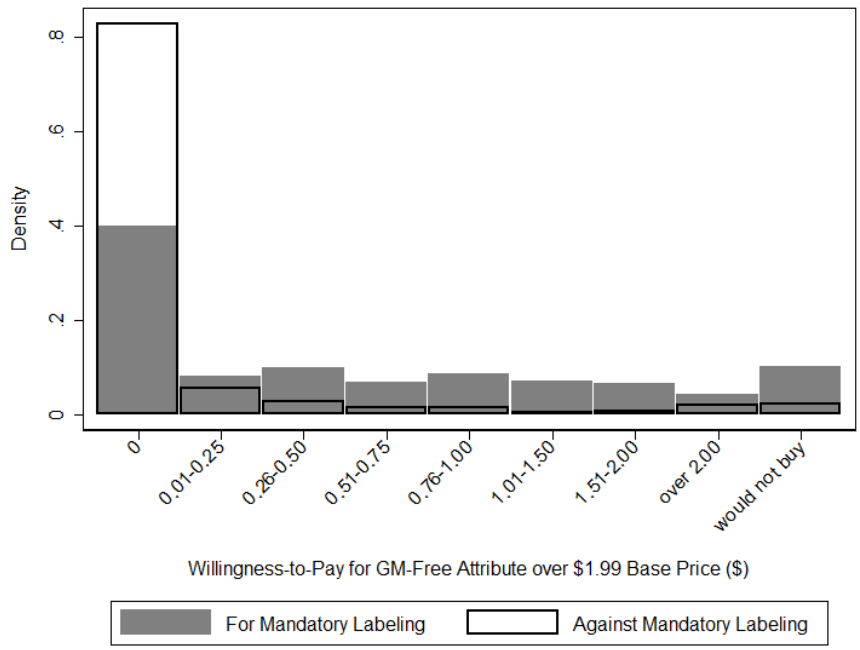


Figure 2.2: Willingness-to-Pay by Willingness to Vote in favor of Mandatory Labeling

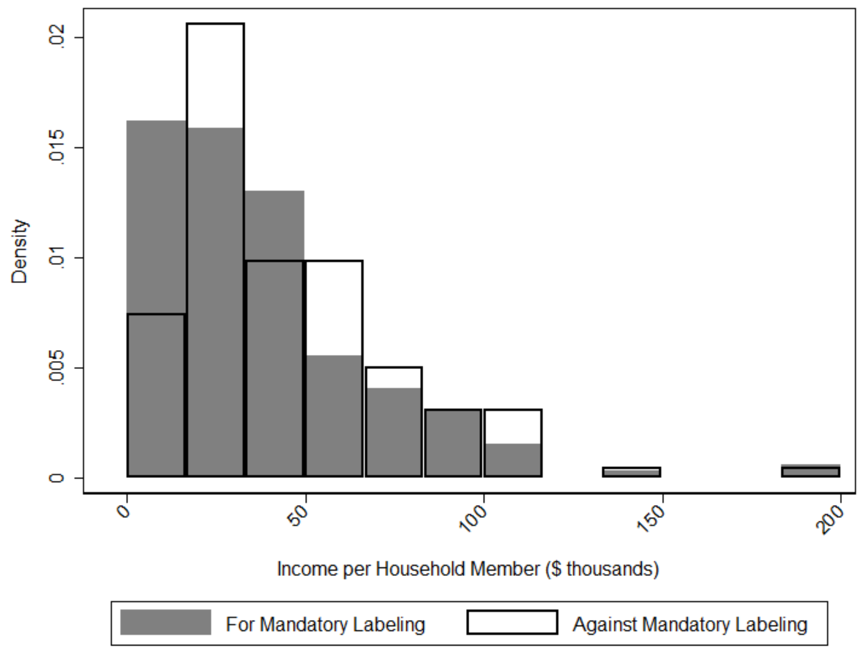


Figure 2.3: Income per Household Member by Willingness to Vote in Favor of Mandatory Labeling

voter support for a ban instead of mandatory labeling are qualitatively very similar.

2.4 Empirical Analysis

Since respondents selected WTP from a payment card, responses are interval-censored and I use interval regression to estimate WTP for the GM-free product. Recall that equation (1) of the conceptual framework suggests that WTP depends only on the marginal utility associated with the additional private benefits of purchasing the benign good, scaled by the marginal utility of income. If concerns about the environment enter into the WTP decision, this would indicate that respondents either believe in the efficacy of green consumption or that they gain satisfaction from making purchases they believe to be ethical or socially responsible.

The estimation results for the full sample are presented in the first column of Table 2. The coefficients on basic demographic variables are consistent with the prior literature on WTP for GM-free food. Age is strongly negatively associated with WTP, with a ten year increase in age associated with a nine cent decrease in WTP. The coefficient on years of education is positive and significant at the 10% level, while the coefficient on the male indicator is negative but insignificant. Low income is defined as household income below the 25th percentile in my sample, and high income as income above the 75th percentile, although all of my results are insensitive to changing these cutoff values. The coefficient on the low income indicator is negative as would be expected but statistically insignificant. The coefficient on high income is small in magnitude and insignificant, which is unsurprising given that income is only important to the extent that it might prevent a consumer from purchasing GM-free food when she has a preference for it.

The indicator variables "Health Safe" and "Health Unsafe" represent consumption safety ratings 1-2 out of 5 and 4-5 out of 5 respectively, and proxy for perceived private benefits of consuming GM-free food. Similarly "Environment Safe" and "Environment Unsafe" proxy for perceived public benefits. The coefficients on these variables have the expected signs but only "Environment Unsafe" is statistically significantly related to WTP. Moreover, environmental concern increases average willingness to pay by \$0.25, whereas concern about health impacts increases average willingness to pay by only \$0.10. Interestingly among my sample, the belief that GM food is unsafe for the environment is a more important determinant of WTP than the belief that GM food is unsafe to consume. Also note that the coefficients on the two "unsafe" variables are larger in magnitude and more strongly significant than those on the two "safe"

Table 2.2: Willingness to Pay for GM-Free Product and Probability of Voting in Favor of Regulation

	WTP	Pr(WTP> 0)	WTP|WTP> 0	Pr(Labeling)	Pr(Ban)
	(1)	(2)	(3)	(4)	(5)
Age (10 yrs)	-8.884^{***}	-0.064^{***}	-9.549^{***}	-0.039^{***}	-0.015
	(1.504)	(0.013)	(2.897)	(0.011)	(0.010)
Education (yrs)	2.269^{*}	0.017^{*}	3.102	0.014^{*}	-0.014^{*}
	(1.161)	(0.010)	(2.227)	(0.008)	(0.008)
Male	-3.332	0.002	-9.013	-0.023	-0.054^{*}
	(4.352)	(0.037)	(8.263)	(0.032)	(0.030)
Low Income	-7.387	-0.002	-13.269	0.103^{***}	0.079^{**}
	(5.478)	(0.049)	(9.845)	(0.038)	(0.037)
High Income	-1.936	-0.020	-1.068	0.002	0.005
	(4.849)	(0.040)	(9.749)	(0.034)	(0.031)
Self-Rep Knowledge	2.055	0.013	2.458	0.010	0.023^{**}
	(1.751)	(0.014)	(3.413)	(0.013)	(0.011)
Test Pass	-11.077^{**}	-0.062	-15.420^{*}	0.035	-0.004
	(4.735)	(0.039)	(9.187)	(0.032)	(0.030)
Health Safe	-7.541	-0.114^{**}	0.870	-0.172^{***}	-0.190^{***}
	(6.572)	(0.057)	(12.364)	(0.057)	(0.053)
Health Unsafe	10.285	-0.037	25.608^{**}	0.081^{**}	0.204^{***}
	(6.466)	(0.058)	(10.304)	(0.039)	(0.048)
Envmt Safe	-6.619	-0.122^{**}	9.454	-0.254^{***}	-0.201^{***}
	(6.659)	(0.056)	(15.258)	(0.059)	(0.049)
Envmt Unsafe	24.849^{***}	0.266^{***}	6.145	0.197^{***}	0.259^{***}
	(6.399)	(0.058)	(10.889)	(0.044)	(0.053)
Constant	37.317^{**}	0.440^{***}	71.727^{**}	0.582^{***}	0.670^{***}
	(18.459)	(0.161)	(33.682)	(0.130)	(0.128)
Observations	658	658	265	709	709

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Columns 2, 4, and 5 are linear probability models with robust standard errors.

variables. In terms of WTP, respondents who were uncertain about GM safety, the omitted category, thus tend to behave more similarly to respondents who believe GM food to be quite or very safe.

Given the large proportion of zero WTP responses, I also run a hurdle model specification where I first estimate the probability that a respondent reports WTP greater than zero and then estimate the level of WTP conditional on such participation. I use a simple linear probability model with heteroskedasticity robust standard errors for the former, estimating the probability that the expression for δ^* given in equation (1) is greater than zero (column 2). Results are qualitatively robust to a probit specification. For the latter I again use interval-censored regression to estimate $\delta^*|\delta^* > 0$ (column 3). Here the results are unchanged by inclusion of the inverse Mills ratio to account for endogeneity. The results indicate that, to some extent, different factors do indeed drive the decision to purchase GM-free food and the decision regarding how high a premium to pay.

Intuitively, the coefficients on the two income variables are close to zero and insignificant in the participation regression, whereas the coefficient on Low Income is negative and large in the conditional WTP regression. These results suggest that income does not affect whether a consumer prefers to purchase GM-free food or not, but does determine how much she is able to spend. A respondent who believes GM food to be safe for consumption is significantly less likely to buy GM-free food at all, but conditional on participation, belief that GM food is unsafe to consume significantly increases WTP by an average of \$0.26. A consumer is willing to spend much more to avoid GM food if she believes it to be associated with health risks. Conversely, belief that GM food is unsafe for the environment significantly increases the probability of participation but not average conditional WTP. Thus public good environmental concerns tend to encourage respondents to "vote" with their product choice, while private good health concerns tend to impel respondents to actually increase spending.

For a simple comparison between the factors underlying consumer and voter choices, column 4 presents estimation results for a linear probability model of voting in favor of the mandatory labeling proposition. The coefficients on the demographic variables are fairly comparable to those in the WTP participation regression, although low income significantly increases the probability of voting in favor to a fairly large degree. Returning to equations (4), (5), and (6) of the model, income is negatively associated with support for the labeling proposition only among those with moderate or high WTP. I test whether it is moderate and high WTP respondents that are driving this result later on. The coefficients on the safety indicators are also comparable to those in column 2, although now the magnitudes of the coefficients are somewhat larger and more strongly significant for the "safe" variables than the "unsafe" variables. Thus the omitted category, those who are uncertain about the safety of GM foods, tend to behave more closely to those who think GM foods to be unsafe. This is the reverse of the WTP results, and suggests that individuals may be more cautious or pessimistic about GM food when acting as voters on mandatory labeling than as consumers.

Column 5 presents equivalent estimation results for the vote to ban. While age is a less significant determinant of the probability of supporting a ban, years of education is here weakly significantly negatively correlated. Comparing the predicted determinants of $dV_{1,2}$ to those of δ^* and $dV_{1,3}$, this finding perhaps suggests that the marginal utility of freedom of choice is increasing in education. The coefficient on self-reported knowledge about GM food is significantly positive, perhaps suggesting that conviction about damages or risks associated with the technology make voters more willing to forego option value in favor of strict regulation. The coefficients on the variables regarding the safety of GM food have the expected signs and are all strongly significant, with the magnitudes here somewhat larger for the "unsafe" indicators. Although the differences are small, uncertain voters tend to behave more similarly to voters who perceive GM foods to be safe, consistent with uncertainty about the technology increasing option value. Again all results in columns 4 and 5 are robust to use of a probit instead of a linear probability model.

Assuming that voters will support mandatory labeling if doing so increases their utility, in estimating the probability that a respondent votes in favor of mandatory labeling I am estimating $\Pr(dV_{1,2} > 0)$. Equations (4), (5), and (6) suggest that the sample would ideally be split into three groups depending on the magnitudes of WTP relative to the premia for GM-free food under voluntary and mandatory labeling. These premia are imprecisely known so, as in Table 1, I only divide the sample into respondents with zero willingness to pay, which will capture a greater proportion of individuals represented by equation (4), those with moderate willingness to pay, which will capture a greater proportion of individuals represented by equations (5), and those with high WTP to capture respondents represented by equation (6). Again results are not sensitive to changing the boundaries for these categorizations.

Within each category, I estimate $\Pr(dV_{1,2} > 0)$ using a simple linear probability model or probit. Sample selection bias is not a concern as the goal is to assess the determinants of the voting decision conditional on WTP and to compare them across different WTP categories, not to generalize the estimates to the population. Columns 1, 2, and 3 of Table 3 present results, omitting coefficients on demographic and knowledge-related variables as they

Table 2.3: Probability of Voting in Favor of Regulation, by Willingness to Pay

	Pr(Voting in Favor of Mandatory Labeling) |Low WTP	|Mid WTP	|High WTP	Pr(Voting in Favor of a Ban) |Low/Mid WTP	|High WTP
	(1)	(2)	(3)	(4)	(5)
Low Income	0.168***	0.056	0.055	0.103**	0.007
	(0.060)	(0.071)	(0.057)	(0.043)	(0.078)
High Income	0.006	−0.014	0.017	0.007	0.003
	(0.046)	(0.079)	(0.059)	(0.034)	(0.070)
Health Safe	−0.072	−0.264**	−0.022	−0.128**	−0.318**
	(0.087)	(0.119)	(0.069)	(0.057)	(0.131)
Health Unsafe	0.134	0.071	0.052	0.178***	0.210**
	(0.083)	(0.067)	(0.048)	(0.059)	(0.089)
Envmt Safe	−0.276***	−0.140	−0.181*	−0.233***	−0.061
	(0.077)	(0.154)	(0.105)	(0.050)	(0.135)
Envmt Unsafe	0.250***	0.115	0.033	0.321***	0.127
	(0.083)	(0.084)	(0.064)	(0.062)	(0.109)
Constant	0.405**	0.683***	0.819***	0.687***	0.708**
	(0.180)	(0.243)	(0.239)	(0.134)	(0.329)
Observations	393	138	178	531	178

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All columns are linear probability models with robust standard errors.

are largely similar to those in Table 2. For income, equation (4) suggests a positive relationship with the probability of supporting the mandatory labeling proposition for low WTP respondents while equation (6) suggests a negative relationship among high WTP respondents. Column 3 reports a positive coefficient on the low income indicator among the latter as expected, although it is insignificant, and a coefficient close to zero on the high income indicator. For low WTP respondents, however, we expect a negative coefficient on low income but observe a large positive coefficient significant at the 1% level. The probability of a low income respondent with zero WTP voting in favor of mandatory labeling is almost 17% higher than that of a wealthier respondent. This result further suggests that low income voters may choose to exercise their power as voters where they could not as consumers, without adequately accounting for the costs of regulation

Among the zero WTP subsample, only the environmental safety indicators were significant and their coefficients much larger than those on the consumption safety indicators. This finding is consistent with equation (4), which suggested that individuals with low WTP should be unconcerned with the private benefits in deciding their vote on mandatory labeling since they will not purchase GM-free food and receive those private benefits. In contrast, among those with moderate WTP, as represented by equation (5), perceived consumer safety is a significant determinant of the voting decision since δ^* enters into the expression for the change in utility. Among the high WTP subsample none of the safety indicators are significant and three out of four of the coefficients are close to zero, again indicating that respondents with high WTP favor the regulation regardless of their other characteristics. However, small sample size may be problematic here as among those with high WTP only 13 of 127 respondents were against labeling. Also note that the estimated constants increase as we move to subsamples with higher WTP, as expected.

For the vote to ban GM food, I estimate $\Pr(dV_{1,3} > 0)$ by coarsely dividing the sample into respondents with zero to moderate WTP, representing a larger share of individuals captured by equation (7), and those with high WTP, representing mostly individuals described by equation (8). Here the expected relationship to income is unclear among the former group, although more likely to be positive given the dominance of respondents with zero WTP, and negative among the latter. However, for high WTP respondents, I find essentially zero relationship between income and the probability of a vote in favor, whilst I again find a positive and significant effect of low income among low or moderate WTP respondents. As with the mandatory labeling decision, this observation suggests that the cost burden of a ban is not adequately acknowledged and that low income individuals may tend to over-vote relative to their actual WTP as a result.

Both environmental safety and consumption safety are important factors in the decision to vote in favor of a ban among low or moderate WTP respondents, as equation (7) suggests since both public benefits and private benefits, via their role in δ^*, enter into the expression for the associated change in utility. Interestingly though, health concerns tend to be the more important determinant among the high WTP subsample. This appears to be in contrast to the predictions of equation (8), but may just highlight that concerns about the health risks associated with GM food could be either a private or a public matter. Those who feel GM foods are unsafe for consumption may be concerned about health effects for all consumers.

2.5 Conclusion

A production technology is controversial when there is disagreement regarding its associated environmental or social externalities, and often its private consumption risks. Individuals can and do respond to such technologies as voters deciding to support regulation and as consumers choosing to pay a premium for an alternative that avoids the technology. In this paper, I formalize the relationship between WTP and willingness to vote for different forms of regulation. Assuming a very general utility function, the model suggests that WTP is an important factor in the probability of voting in favor of regulation, but that its effect is not smooth. Instead, WTP divides the population of potential voters into subgroups for whom the other factors that determine changes in utility between regulatory options are of different relative importance, most notably income.

The recent California ballot proposition on mandatory labeling of GM food provided a novel opportunity to examine both consumer and voter behavior with real-world context in response to the same topical and controversial technology. Among my survey sample, respondents are overall more concerned about the environmental safety of genetically engineered crops than they are about the safety of GM food for human health. I find that WTP for GM-free food indeed depends on both environmental and health concerns, but that the former have a greater impact. However, the results also suggest that perceived environmental risks encourage consumers to "vote" by choosing GM-free food whereas perceived health risks increase the actual level of WTP.

The results also exhibit some potentially broader patterns regarding the differentiated impacts of individual characteristics on consumer and voter behavior. Those who are uncertain about the safety of GM food tend more towards the lower WTP of consumers who are not concerned, but more towards the higher probability of voting in favor of mandatory labeling of voters who are very concerned. In relative terms, they may tend to "over-vote" but underspend on GM-free food. It is unclear whether the consumer or voter decision is more revealing of the individual's true preferences, although the immediacy of the associated cost may imply that the WTP decision is more informed and rational. In the case of voting to ban GM foods however, uncertain voters tend more toward optimism, perhaps motivated by the more obvious consequences of this regulatory option and positive option value.

I find only a weak relationship between income and WTP, whereas willingness to vote for regulation is positively associated with low income among respondents for whom such a relationship is not predicted by my utility maximization framework. The model suggests that among respondents with low WTP, the probability of voting in favor of regulation decreases in the marginal utility of income, but I find evidence of the opposite effect. Low income individuals are perhaps more likely to vote in favor of regulation because they are more constrained in their ability to pay the premium for GM-free food and the costs associated with regulation are less apparent. If this result persists in other contexts, there may be significant implications regarding the efficiency of putting public goods up for popular vote, particularly among low income populations.

3 Trade Effects of the Methyl Bromide Phase-out

3.1 Introduction

The pollution haven hypothesis (PHH) posits that countries with relatively strict pollution regulation will tend to import more of their pollution intensive "dirty" goods from countries with weaker regulation (Copeland and Taylor, 2003). Since developed countries often have more stringent regulation, while developing countries tend to have weak, unenforced, or absent regulation, trade in dirty goods may place undue pollution burdens on the poor. Differences in environmental regulation may also undermine attempts to reduce global environmental damages undertaken by regulating countries, as with the potential for carbon leakage resulting from sub-global climate policy (Babiker, 2005). Producers often appeal to the same notion from the alternative perspective of foreign competition; they argue that unilateral increases in the stringency of domestic pollution regulation leave them at an unfair disadvantage relative to their foreign counterparts, and overly vulnerable to import competition.

The intuition underlying the PHH is clear and, in the past two decades, has motivated a host of empirical studies seeking to estimate the impact of environmental regulation on trade patterns. While this work faces a number of data-driven obstacles, more recent studies have found moderate support for the hypothesis (Ederington et al., 2005, Levinson and Taylor, 2008, Millimet and Roy, 2015). The existing literature, however, has focused exclusively on manufacturing industries, although the basic argument applies equally to the agricultural sector and the pollutants generated by agricultural activity, including pesticides. In this paper, I test the PHH in an agricultural setting by estimating the impact of cross-country differences in methyl bromide (MeBr) regulation, generated by the pesticide's addition to the Montreal Protocol on Substances that Deplete the Ozone Layer, on trade in agricultural goods

Prior to the Copenhagen amendment to the Montreal Protocol, MeBr was used extensively as a pre-plant soil fumigant in the cultivation of a number of fruit and vegetable crops. Its broad herbicidal, fungicidal, and nematicidal properties ensured its rapid adoption in the 1960's, almost to the exclusion of other chemical pesticides for some crops (Methyl Bromide Technical Options Committee, 1998). Noling and Becker (1994) reports that the availability of a reliable and affordable pre-plant soil fumigant was in fact critical to the development of sustained high-value cropping systems. Prior to the introduction of MeBr, cultivation of many specialty crops was nomadic, as pest pressures would reach intolerable levels if crops were grown in immediate succession for more than two to three seasons. Such a nomadic system is no longer feasible in developed countries, given the lack of suitable unused land.

Unfortunately, MeBr is also an ozone-depletant and was thus added to the Montreal Protocol in 1994. The protocol set phaseout schedules for all pre-plant uses of MeBr with differing deadlines for developed (non-article 5) and developing (article 5) countries. The target year for full phaseout was set to 2005 for developed countries and 2015 for developing countries, with Critical Use Exemptions (CUEs) granted to growers of particular crops in a number of countries on a case-by-case basis. In fact, producers have applied for CUEs largely on the grounds that being prevented from using MeBr would leave them at an unfair disadvantage relative to foreign producers. Several predictive assessments of the economic impacts of the MeBr ban also noted the possibility of displacement of domestic production by imports for certain crops (Lynch et al., 2005, Carter et al., 2005).

In this paper, I use the resulting variation in MeBr allowable usage to assess the impact of differences in regulation between trading partners on export volumes, and find strong evidence that relatively strict exporter regulation decreases exports. The magnitude of the effect varies across crops, and tends to be largest for those that used MeBr heavily at baseline. Not only is this the first ex-post test of the PHH in the context of MeBr, and agricultural pollutants more generally, but this example of cross-country differences in pollution regulation is both more quantifiable and more convincingly exogenous than most prior studies. The rest of the paper proceeds as follows: Section 2 provides a brief background on the pollution haven hypothesis and reviews the recent empirical literature, Section 3 describes the Montreal Protocol in further detail, Section 4 presents the empirical analysis, and Section 5 concludes.

3.2 The Pollution Haven Hypothesis

A simple partial equilibrium example readily demonstrates how differences in environmental regulation may affect trade. Following Chapter 5 of Copeland and Taylor (2003), consider a two region, two good setting with exogenously determined environmental regulation and input prices. Call the regions $North$ and $South$, and assume that they have identical endowments, preferences, and production technologies. Let the two goods be X and Y, where production of X uses some polluting input, such as MeBr, or generates pollution as a joint output, such as carbon dioxide. Production of Y does not pollute. Let Y be the numeraire, and the price of X relative to Y be p. In each region, the supply of each good is a function of p, the stringency of environmental regulation e, and the endowments of inputs, I: $X = x(p, e, I)$ and $Y = y(p, e, I)$. The relative supply of X to Y is therefore $S(p, e, I) = \frac{x(p,e,I)}{y(p,e,I)}$.

Assuming that an increase in environmental stringency has some positive effect on the cost of producing X but not on the cost of producing Y, $\frac{\partial x}{\partial e} < 0$ while $\frac{\partial y}{\partial e} = 0$. Thus $\frac{\partial S}{\partial e} < 0$. So an increase in environmental stringency decreases the relative supply of the good that pollutes, X. Now suppose that North has stricter pollution regulation than South, in the form of a higher pollution tax or a limit on the use of a polluting input, i.e. $e_{North} > e_{South}$. Then $S_{North}(p, e_{North}, I) < S_{South}(p, e_{South}, I)$. Since demand is identical in the two regions, $p_{North} > p_{South}$ in autarky. Under free trade, we expect the world price will be somewhere between the two autarky prices, causing $North$ to import X and export Y, and vice versa for South.

In the context of this paper, where the polluting input under consideration is MeBr, the polluting good can be interpreted as the aggregate "fruits and vegetables" while the clean good may be manufactures or industrial commodities. Alternatively, the polluting good can be interpreted as those crops that rely most heavily on MeBr applications, while the clean good consists of those crops that use little or no MeBr. This latter interpretation is perhaps more appropriate if land is considered a relatively fixed endowment that is only useful for the cultivation of agricultural goods.

It is also important to note that the effects presented are only marginal effects, and may be dwarfed by other drivers of comparative advantage. The most common explanation as to why pollution havens have proven difficult to identify is that factor endowments are much more important determinants of production location than environmental regulation. If the costs imposed by more stringent environmental regulation are small compared to other input costs, for example, it is less likely that production will relocate following regulation changes. In addition, the analysis is complicated by general equilibrium effects such as changes in factor prices (Karp, 2011).

A number of empirical studies estimate the effects of pollution regulation on trade flows or production location decisions. Copeland and Taylor (2004) and Brunnermeier and Levinson (2004) provide comprehensive reviews of the extent of this literature until 2004, and critique the cross-sectional approach that much of it involves. More recent analyses, however, use panel data to estimate the effect of environmental regulation on US imports or outbound foreign direct investment (FDI). These studies typically estimate a log-linear model of the form:

$$log(Y_{it}) = \beta_1 log(R_{it}) + \beta_2 log(X_{it}) + \gamma_i + \lambda_t + \epsilon_{it}$$

where Y_{it} is either US net imports or outbound FDI in industry i and year t, R_{it} is an industry specific measure of environmental regulation, X_{it} is a vector of industry characteristics that change over time such as factor intensities or import tariffs, and γ_i and λ_t are industry and time fixed effects respectively. Models of this form are extensions of the gravity model of trade, so named because they estimate bilateral trade as proportional to the product of the size of the two economies ("mass"), divided by various measures of trade frictions ("distance") (Rose, 2004).

In contrast to the earlier literature, these analyses often do find evidence that environmental regulation drives trade or foreign investment to some degree. Levinson and Taylor (2008), for example, find that pollution abatement operating costs (PAOCs), a common measure of environmental regulatory stringency, have a significant positive impact on US net imports from Canada and Mexico in the 130 manufacturing industries included in their sample. Ederington et al. (2005) estimate the effect of PAOCs on US net imports separately for strict and lax regulation countries, and also separately for more and less easily transported goods, and find statistically significant pollution haven effects for imports from countries with low regulatory stringency and for imports in more "footloose" industries. Cole and Elliott (2005) regress the share of US outbound FDI on industry PAOCs and also find a positive and significant effect, suggesting that strict domestic environmental regulation drives firms to invest more abroad. More recently, Millimet and Roy (2015) find that US state environmental regulation negatively affects inbound FDI, and that the estimated effect is larger when controlling for endogeneity.

The fact that these studies focus on US measures of imports or FDI is indicative of the challenge of finding appropriate data with which to test the PHH. The primary obstacle is in obtaining even plausible, if not reliable, measures of the stringency of environmental regulation. Direct data is not readily available, hence the frequent use of PAOCs, which are collected annually by a Census Bureau survey. Studies that use PAOCs are careful to explain that this measure is a problematic proxy for environmental stringency. It is even more challenging to find measures of environmental regulation for other countries, and so foreign regulation is most often omitted from the empirical model (see Dean et al. (2009) and Kellenberg (2009) for two exceptions). Leaving other countries' environmental regulation in the error term may lead to biased estimates of the effect of domestic regulation on trade.

In addition, lack of data on foreign regulation necessitates that analyses are conducted at the aggregate level of total US imports from all countries. As the results in Ederington et al. (2005) suggest, there is important unobserved heterogeneity at both the industry and country level. The analysis of the phase

Table 3.1: Top 20 Heaviest Uses of Methyl Bromide in California in 1991

Rank		Total Lbs Applied		Lbs per Acre		% Acres Treated
1	Strawberry	4,537,792	Plums	582	Smr Squash	100
2	Carrots	1,294,670	Citrus	420	Figs	100
3	Grapes	904,481	Persimmon	405	Asparagus	100
4	Peaches	893,892	Greens	392	Melons	100
5	Nectarines	348,479	Grapes	376	Celery	92
6	Plums	278,968	Onion	340	Eggplant	88
7	Tomatoes	211,958	Eggplant	334	Persimmon	88
8	Swt Potatoes	190,708	Asparagus	298	Watermelon	87
9	Peppers	146,877	Brussel Sprts	281	Pumpkin	85
10	Prunes	138,674	Peppers	277	Lettuce	76
11	Lettuce	79,105	Cucumbers	269	Carrots	73
12	Cherries	72,218	Celery	269	Greens	72
13	Citrus	66,368	Pumpkin	265	Cauliflower	70
14	Eggplant	65,318	Lettuce	237	Peppers	70
15	Apples	63,986	Smrr Squash	234	Tomatoes	69
16	Broccoli	46,192	Strawberry	230	Avocado	66
17	Melons	42,332	Peaches	229	Nectarines	66
18	Apricots	38,283	Swt Potatoes	228	Swt Potatoes	60
19	Celery	22,512	Nectarines	222	Apples	59
20	Cauliflower	19,248	Apricots	219	Broccoli	59

out of Methyl Bromide in this paper benefits from an explicit measure of the stringency of regulation that is available for all countries. Further, the cross-country differences in MeBr regulation are more defensibly exogenous then measures used in the manufacturing literature, as the phaseout schedule was determined by a country's development status and accession to the protocol and not on the size of their agricultural exports. This is discussed in greater detail in the following section.

3.3 Methyl Bromide and the Montreal Protocol

MeBr is a broad-spectrum pesticide, used extensively as a pre-plant soil fumigant in the cultivation of a number of specialty crops prior to its addition to the Montreal Protocol. MeBr also has uses in post-harvest storage and for fumigation of structures, as well as in quarantine and pre-shipment which are

	1995-1998	1999-2000	2001	2002	2003-2004	2005-2014	2015
Methyl Bromide Production and Consumption Allowed for Non-Article 5 Participants	Freeze at 1991 Baseline	75% of Baseline	50% of Baseline		70% of Baseline	Critical Uses Only	
Methyl Bromide Production and Consumption Allowed for Article 5 Participants				Freeze at 1995-1998 Baseline		80% of Baseline	Critical Uses Only

Figure 3.1: Montreal Protocol Timeline for Phaseout of Methyl Bromide

excluded from the protocol. In 1991, the baseline year used for the regulation, approximately 72,000 metric tonnes of MeBr were consumed for fumigation purposes, 75% of which were used for soil treatment (Methyl Bromide Technical Options Committee, 1998). Usage of course varied widely across crops, as Table 1 demonstrates. Although pesticide use data is notoriously sparse, an exception is California's Pesticide Use Reporting Database which records all applications of all pesticides at the field level. Table 1 presents total pounds of MeBr applied, average pounds used per treated acre, and the percent of planted acres treated with MeBr, for the top 20 crops within each category in California in 1991. The most reliant crops on a global basis included strawberries, tomatoes, peppers, and melons and cucumbers.

The Copenhagen Amendment to the Montreal Protocol set forth a broad timeline specifying the dates by which ratified countries were to have reduced or phased out pre-plant soil fumigation uses of MeBr (see Figure 1). The precise legislation that would keep countries in compliance with the agreement was left at the discretion of the individual countries, with UNEP undertaking annual compliance checks. Schafer (1999) provides results from a survey of the regulations used by each country to enforce the timeline and shows the diverse strategies that have been adopted. Specific regulations reported include import and production caps, tradable allowances, and usage taxes, all of which have the same effect of increasing the costs of using MeBr. While it is not possible to know which parties were in full compliance each year, the survey suggests that enforcement of the timeline has been satisfactory overall, as do overall production and consumption statistics. Some European countries, such as Sweden and Denmark, enacted more aggressive phaseout schedules, while MeBr was never adopted to any significant extent in Germany due to local pollution and health and safety concerns.

The biggest failure of the MeBr phaseout, and indeed of the Montreal Protocol as a whole, was the continuation of Critical Use Exemptions (CUEs) well beyond the target. Although MeBr was scheduled to have been fully phased out in non-article 5 countries by 2005, usage remained at 1,363 metric tonnes in the US in 2009, over 16% of baseline consumption, due to the persistence of CUEs. Critics argued that concessions made to industry, particularly to US strawberry and tomato producers, demonstrated a shift away from concern for social welfare and towards special interests (Gareau, 2010). The situation was largely remedied by 2014, with pre-plant CUEs granted only to California strawberry growers experiencing particular pest conditions (U.S. Environmental Protection Agency, 2015).

The argument producers made in support of their applications for critical use exemptions was essentially the PHH argument, although made from the perspective of competitiveness losses rather than concern regarding an undue pollution burden on poor countries. The underlying mechanism of higher production costs associated with regulatory stringency, as clarified in Section 2, is the same. The irony of the argument in the case of MeBr CUEs was that exemptions were largely the exception rather than the rule, so according to the logic of the PHH it was the exempt producers who may have had an unfair competitive advantage. I test whether this was indeed the case in the analysis.

It should be noted that the case of MeBr regulation does differ from the standard PHH setting in important ways. First, MeBr is a discretionary input rather than a joint output, so apparent pollution haven driven trade does not necessarily imply that usage of MeBr in unregulated countries is increasing. While the same caveat applies to manufacturing pollutants, it is much less likely that unregulated countries have less pollution intensive methods of producing manufactures. Also, MeBr has both local and global environmental effects, but it is the global issue of ozone depletion that has spurred regulation and is of most concern to regulators. So the location of MeBr application is less relevant in terms of environmental justice than, for example, the location of manufacturing that results in local air quality degradation. It is more akin to the issue of carbon leakage associated with sub-global greenhouse gas regulation in this regard.

3.4 Empirical Analysis

As noted previously, the MeBr phaseout lends itself to empirical analysis in a number of ways that the regulation of manufacturing pollutants, as examined by the prior literature, do not. First, the phaseout schedule constitutes a straightforward and direct measure of regulation. Rather than using operating costs of compliance as a noisy proxy for the stringency of regulation, the phaseout schedule is precisely the level of regulation itself. As discussed above, the intended level of regulation does not determine the particular legislation imposed so the actual effect on crop production costs is unknown, but a high correlation between the intended level of regulation and production costs is plausible.

Second, this measure of regulatory stringency is available for every country, since the Montreal Protocol specifies a schedule for article 5 (developed) and non-article 5 (developing) countries, and contains clear documentation of which countries fall into each group, along with the year of each country's ratification of, or accession to, the protocol. Third, since the phaseout was applied in a relatively uniform manner, regulation of MeBr is more plausibly exogenous. Thus there is not a need to find valid instruments for the regulation, a significant challenge in PHH analyses of manufacturing (Levinson and Taylor, 2008). The CUEs do complicate this claim, but superficially at least the exemptions were granted to producers based on dependence on MeBr rather than the economic importance of trade in a crop to a particular country. The over-compliance mentioned in some EU countries may also threaten exogeneity, but I find no evidence of this.

3.4.1 Data

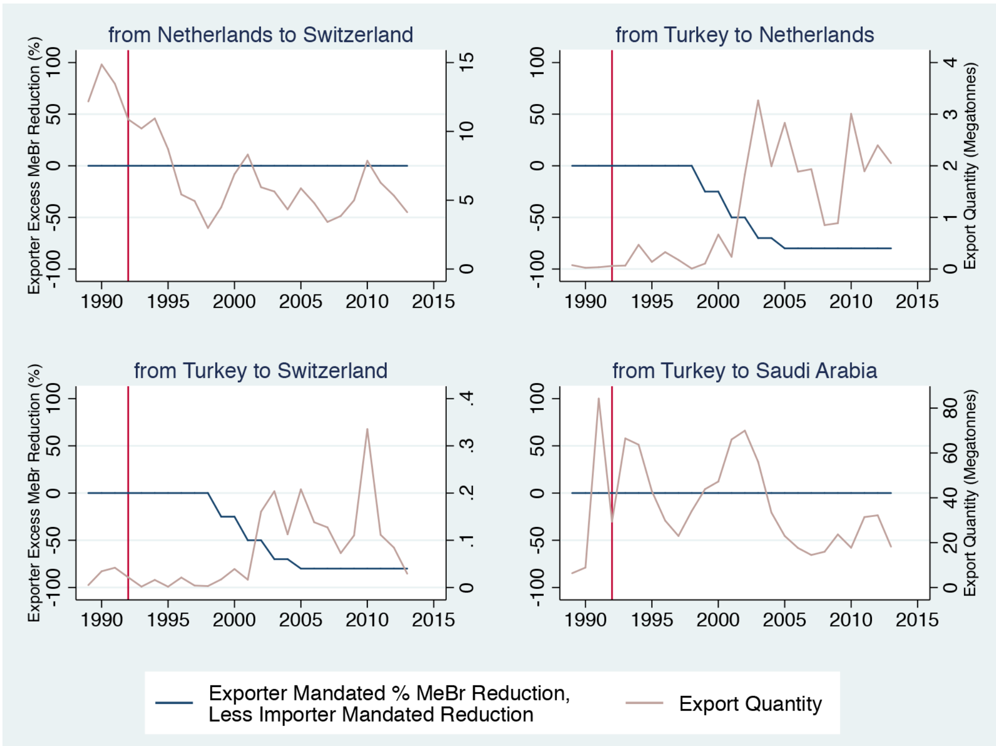
I use bilateral trade data on 53 fruit and vegetable categories covering the period 1989 to 2013, taken from the United Nations' Commodity Trade Statistics Database (COMTRADE) at the 6-digit Harmonized System classification code level. Each trade quantity is recorded up to twice in this dataset, reported once by country i as an export to country j, and once by country j as an import from country i. I choose the data from the reporter that reports for more years for the given trade flow. Where both reporters provide data for the same number of years, I use the importing country's records based on the rationale that customs officers tend to pay closer attention to the origin of imports than the destination of exports for the application of tariffs (Gaulier and Zignago, 2010). As a robustness check, all analyses are replicated using only reported exports or reported imports, and the overall conclusions are unchanged[9].

Tariff data is taken from the Trade Analysis and Information System (TRAINS), published by the United Nations Conference on Trade and Development. Simple and weighted average values of the effectively applied tariff

[9]The problem of discrepancies in trade data has been referred to in the broader gravity model literature, but no standard in reconciling exports and mirrored imports has developed. Other approaches to that taken in this paper include using weighted averages of the two reported values, and estimating indices of the reliability of each reporting country.

rate are available at the 6-digit HS level from 1979 to 2010. Unfortunately, a majority of observations are present in either the COMTRADE data or the TRAINS data, but not both. Rather than attempt to interpolate tariff levels or assume that the absence of TRAINS data signifies a zero tariff, I estimate models both including and excluding tariff covariates. Omitting observations for which tariff data is unavailable does not appear to introduce significant selection bias into the results. Data on populations, GDP, and exchange rates come from the USDA's International Macroeconomic Dataset.

The level of MeBr regulation is constructed from Montreal Protocol documentation. Each exporting and importing country is assigned a degree of regulatory stringency in each year, ranging from 0 signifying no limitation on MeBr use, to 1 signifying 100% required reduction in baseline use of MeBr. The level of regulation is determined by each country's status as an article 5 or non-article 5 country, and the timeline specified in the protocol. The variable is set to 0 for an observation if the year precedes the particular country's year of accession or ratification. Lastly, I modify the variable to account for those European Union Countries that adopted their own, more aggressive schedules. The difference in this level of regulation between two trading partners constitutes the variable of interest for this analysis. Although it takes on only a limited number of observations given its construction, it is modeled as a continuous index. A graphical example of the difference in regulation variable is given in Figure 2 to further illustrate the identification strategy.



Netherlands and Sweden are both non-article 5 countries, while Turkey and Saudi Arabia are both article 5. These trade flows are chosen as an example on the basis that tomatoes were the largest global pre-plant use of MeBr, and data for these trading partners are available for all 25 years.

Figure 3.2: Differences in Regulation and Tomato Exports

There is an issue in modeling CUEs that arises from the fact that the parties to the protocol only started granting them in 2005, when MeBr was supposed to have been otherwise fully phased out in developed countries. If CUEs were simply included in the variable described above, there would be sudden decreases between 2004, when all commodities were subject to the same level of phaseout, and 2005, when some crops faced a complete ban on MeBr while others were exempt. Instead I estimate the effects of CUEs separately from the primary variable of interest by including importer and exporter CUE indicator variables. Since CUEs apply to only a very small percentage of the observations in the data, this is likely not a hugely important distinction, but it further allows us to examine whether CUEs provided an unfair competitive advantage as mentioned above.

Another potential concern already mentioned is that CUEs may be endogenous, specifically that they were granted to particularly large and powerful producers that tend to have greater exports. At least officially, this is not the case. UNEP's Methyl Bromide Technical Options Committee, which grants all exemptions, reports that its decisions are based on the feasibility of other pest control options rather than economic arguments. This is somewhat supported by the pattern of CUEs that have been granted each year. In 2005, they were granted to no more than two of the top ten exporters of any given crop with the exception of strawberries, for which four of the top ten exporters received exemptionss. By 2008, CUEs were approved for only one top ten exporter of each crop, including strawberries.

3.4.2 Estimation and Results

The empirical pollution haven literature and the gravity model of bilateral trade, suggest the following estimation equation:

$$log(Q_{cijt}) = \beta_1(R_{cit} - R_{cjt}) + log(\beta_2 X_{it}) + log(\beta_3 X_{jt}) + \beta_4 \tau_{cijt} + \mu_{cij} + \lambda_t + \epsilon_{cijt}$$

where Q_{cijt} is the quantity of exports of commodity c from country i to country j, R_{cit} and R_{cjt} are the constructed MeBr regulation variable, X_{it} and X_{jt} are time varying characteristics of i and j including population, GDP, and exchange rates versus the US dollar, τ_{cijt} is the average tariff rate, and μ_{cij} and λ_t are commodity-country-pair and time fixed effects respectively. Commodity-country-pair fixed effects control for differences in average volumes of trade across commodities, based on preferences and ease of transportation, as well as many of the standard entries into gravity equations, such as the distance between the two countries, existence of a common border, shared language or colonial history, and whether either country has an ocean border. Time fixed effects are included to account for increasing globalization and relevant global shocks such as oil prices.

In this model, a negative value of β_1, the coefficient on the difference in regulation variable, would constitute support for the PHH. Since R_{cit} and R_{cjt} range between 0 and 1, with a higher value representing more stringent regulation, the pollution haven argument would predict that exports of MeBr intensive goods from country i to country j are largest when i is unregulated and j is fully regulated ($R_{cit} - R_{cjt} = -1$) and that exports would be smallest when the opposite pattern of regulation holds ($R_{cit} - R_{cjt} = 1$). The difference variable can be thought of as the exporter's excess regulatory burden relative to the importer.

Table 2 presents estimation results for regressions pooled across commodities. Column 1 contains estimates from using all countries for which tariff

Table 3.2: Exports of All Fresh Fruits and Vegetables (HS 07 and 08)

	(1)	(2)	(3)	(4)	(5)
Reg Difference	-0.377***	-0.393***	-0.287***		-0.376***
	(0.130)	(0.130)	(0.111)		(0.131)
Diff < 0				0.195*	
				(0.118)	
Diff > 0				-0.205*	
				(0.124)	
Exporter CUE	-0.077	-0.021	-0.033	-0.118**	-0.037
	(0.050)	(0.042)	(0.050)	(0.052)	(0.077)
Importer CUE	0.099	0.152	-0.115	0.128	0.094
	(0.098)	(0.104)	(0.139)	(0.097)	(0.099)
Diff x Exp CUE					-0.143
					(0.236)
Exp GDP	0.183	0.337	0.128	0.278	0.183
	(0.281)	(0.273)	(0.329)	(0.283)	(0.281)
Imp GDP	0.767***	0.938***	0.679***	0.703***	0.767***
	(0.250)	(0.270)	(0.172)	(0.253)	(0.250)
Exp Exchange	0.177***	0.153**	0.119**	0.196***	0.177***
	(0.063)	(0.064)	(0.051)	(0.068)	(0.063)
Imp Exchange	-0.418**	-0.385**	-0.164**	-0.441**	-0.418**
	(0.187)	(0.172)	(0.067)	(0.198)	(0.186)
No Tariff	-0.019	-0.008		-0.015	-0.019
	(0.061)	(0.061)		(0.063)	(0.061)
High Tariff	-0.149***	-0.153***		-0.149***	-0.149***
	(0.039)	(0.041)		(0.039)	(0.039)
Countries†	All	Limited	All	All	All
Observations	637,131	496,560	925,360	637,131	637,131

†"All" indicates all countries are included for which data are available; "Limited" indicates that countries with more stringent domestic MeBr regulation are excluded. All regressions are log-linear and include exporter-importer-commodity fixed effects and year fixed effects. Standard errors in parentheses are two-way clustered by exporter and importer; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

data are available. Since the model is log-linear, to avoid dropping observations with zero tariff the tariff is represented by indicators for zero tariff and a tariff rate in the 75th percentile for the particular crop. The strongly significant negative estimate of β_1 is consistent with the PHH, suggesting that 100% excess exporter regulation relative to the importer decreases the quantity of that trade flow by $1 - exp(-0.377) = 31\%$. Exporter and importer CUEs, however, are not significantly associated with export quantity. The coefficients on the remainder of the covariates are unsurprising. For this and all subsequent regressions, standard errors are two-way clustered by importer and exporter (Cameron et al., 2011).

The second and third columns of Table 2 provide estimation results from modifying the sample used. Column 2 excludes those European Union countries with more stringent domestic MeBr regulation than called for by the Montreal Protocol, as both exporters and importers. The coefficient on the variable of interest is still strongly significant and very close in magnitude, with 100% regulation of the exporter and no regulation of the importer decreasing exports by 32% on average, relative to the scenario where both countries are regulated equally. Column 3 excludes countries for which tariff data are unavailable, and although the estimate of β_1 is slightly smaller, the sign and significance are unchanged.

In Column 4 I replace the difference in regulation variable with two indicators for whether that difference is positive or negative, i.e. for whether the exporter is more or less regulated than the importer respectively, with the rationale that the continuous index variable may be overly specific. Use of two indicator variables also allows for the possibility that the effect of differences in regulation may not be symmetric, namely that we may expect an increase in exports associated with a less-regulated exporter to be different in magnitude than the decrease in exports associated with a more-regulated exporter. I find the expected signs on the coefficients of the two indicator variables, and more surprisingly I find no evidence of asymmetry in the effect sizes. Compared to an exporter subject to the same MeBr restrictions as its trading partner, a less-regulated exporter (Diff< 0) is associated with a 22% increase in exports, while a more-regulated exporter (Diff> 0) is associated with a 19% decrease in exports on average. The coefficient estimates are only weakly significant though and do not provide an improved fit for the data compared to using the continuous index variable itself.

Lastly in Column 5, I return to the difference in regulation variable and further interact it with the indicator variable for an exporter CUE, as the effect of that CUE is likely to depend on the relative strictness of MeBr regulation. A MeBr usage allowance is likely to matter more for a country with a less regulated trading partner than for a country with equally stringent regulation. The coefficients on both the indicator and the interaction term, however, remain insignificant. It is interesting to note that while none of the CUE variables appear to be statistically or economically significantly related with trade volumes, with the exception of the Exporter CUE coefficient in Column 4, the point estimates all have opposite signs than we might expect. A CUE granted to an exporter should increase exports, but I find the opposite. On one hand, this counterintuitive result may indicate a problem with simply lumping all CUEs together, despite the fact that each exemption approves a different quantity of MeBr for a different set of circumstances. Some are much more generous than others. On the other hand, this finding perhaps suggests that CUEs were indeed largely granted to producers that were most dependent on MeBr, and that on average the exemptions did not fully negate the overall regulatory burden.

It is implausible, of course, that the effect of trading partner differences in MeBr regulation on exports should be the same for all crops, particularly in light of Table 1 which showed the variety in baseline crop dependence on MeBr even among its heaviest users. Although MeBr is a broad spectrum pesticide used in a variety of applications, it is certainly more important to the cultivation of some crops than others. US strawberry and tomato growers, for example, argued that their operations would be economically unviable without MeBr. Moreover, as noted in Section 2, if the supply of land allocated to the cultivation of fruits and vegetables is relatively fixed, an increase in the stringency of MeBr regulation may increase exports of crops that rely less on MeBr as they become more profitable compared to MeBr-dependent crops. In other words, it may be more appropriate to switch to the underlying model that considers certain fruits and vegetables to be pollution-intensive and others to be "clean goods".

I thus estimate the same fixed effects model presented in Column 1 of Table 2 separately for each commodity. Estimates of the coefficient on $R_{cit} - R_{cjt}$ are given in Column 1 of Table 3 for vegetables, and Table 4 for fruit. Indeed, there is notable heterogeneity in the coefficient estimates. While the average coefficient is roughly similar in magnitude to that from the pooled regressions, the coefficients range from -0.854 to 0.196. Of the 53 coefficients, only 1 is positive among vegetable crops and 6 among fruit crops, and for the most part they are crops without noted heavy dependence on MeBr. None of the positive coefficients are significant at even the 10% level, so there is no evidence that producers are switching land from MeBr-reliant crops in response to stricter MeBr regulation.

Among the remaining 46 negative coefficients, 7 are significant at the 5 or

Table 3.3: Exports of Fresh Vegetables, by Commodity

	Regulation Difference	Exporter CUE	Importer CUE	N
Potatoes	-0.184	0.778***		16,693
Tomatoes	-0.634**	-0.186	0.053	16,131
Onions, Shallots	-0.527***			21,073
Garlic	-0.289			15,135
Leeks, Etc.	-0.379			10,835
Cauliflower, Broccoli	-0.433			10,723
Brussel Sprouts	-0.726***			5,416
Cabbages, Etc.	-0.616**			13,477
Head Lettuces	-0.762**			9,656
Other Lettuces	-0.784	-0.168	-0.371**	9,361
Witloof Chicory	-0.264			4,149
Other Chicory	-0.449	0.807***	-0.512***	5,647
Carrots, Turnips	-0.390	-0.212**	0.049	13,125
Beetroot, Radishes, Etc.	-0.338			13,293
Cucumbers, Gherkins	-0.538*	0.002	0.214	12,002
Peas	-0.570**			11,034
Beans	-0.675***			14,234
Other Legumes	-0.361			8,506
Asparagus	-0.503	0.119		11,839
Eggplant	-0.410	-0.194	0.411*	10,451
Celery	-0.757			7,390
Mushrooms Agaricus	-0.387			10,785
Other Mushrooms	0.196			8,473
Capsicum	-0.174	-0.444**	0.194	19,887
Spinach	-0.114			6,558

All regressions are log-linear and include exporter-importer and year fixed effects, and covariates from previous pooled regressions. Standard errors are two-way clustered by exporter and importer; * (p<0.10), ** (p<0.05), *** (p<0.01).

Table 3.4: Exports of Fresh Fruit, by Commodity

	Regulation Difference	Exporter CUE	Importer CUE	N
Bananas, Plantains	-0.282			17,498
Dates	-0.352			18,507
Figs	-0.424*			13,583
Pineapples	0.136			17,436
Avocados	-0.472			11,898
Guavas, Mango	0.052			22,367
Oranges	-0.217			15,423
Mandarin, Etc.	-0.453*			12,749
Lemons, Limes	-0.138			5,746
Grapefruit	-0.210			15,255
Other Citrus	0.005			8,997
Grapes	-0.691***			21,401
Watermelons	-0.416	-0.233	0.272	12,300
Other Melons	-0.018	-0.240	-0.244	14,588
Papaws	0.010			9,153
Apples	-0.437*			22,663
Pears, Quinces	-0.349			15,691
Apricots	-0.525*			10,168
Cherries	-0.261			10,815
Peaches, Nectarines	-0.442*			13,745
Plums, Sloes	-0.411*			14,306
Strawberries	-0.590**	-0.088	-0.196	12,498
Raspberries, Etc.	0.143	-0.242	0.099	9,550
Currants, Gooseberries	0.123			3,477
Cranberries, Etc.	-0.854*			10,480
Kiwifruit	-0.066			10,964

All regressions are log-linear and include exporter-importer and year fixed effects, and covariates from previous pooled regressions. Standard errors are two-way clustered by exporter and importer; * (p<0.10), ** (p<0.05), *** (p<0.01).

1% confidence level among vegetable crops and 2 among fruit crops, and can thus be interpreted as supporting the pollution haven hypothesis in this context. Among those crops demonstrating statistically significant relationships between differences in regulation and export quantities, the relationships are economically significant as well. A mandated MeBr reduction of 100% for the exporter and 0% for the importer is associated with an average decrease in exports of 41% (onions) to 53% (lettuces). For two of the most MeBr-dependent crops, such a difference in regulation is associated with a 47% decrease in tomato exports and a 45% decrease in strawberry exports. While these effect sizes may be surprisingly large, it is important to note that a particular export flow may only account for a small share of a country's total exports, and exports further typically account for only a small share of production. Large changes in particular export flows therefore do not necessarily imply large changes in production, or even total exports.

Interestingly, and in comparison to the pooled regression results presented in Table 2, there is evidence of significant effects of CUEs for some crops. In particular, CUEs approved for potato and chicory exporters appear to increase exports on average, consistent with the idea that these exemptions provided an unfair competitive advantage. The magnitudes, over 100%, are perhaps implausible though and may suggest data limitations given the infrequency with which CUEs were granted for these particular crops. For carrot and pepper producers, however, two other crops with heavy baseline use of MeBr, an exporter CUE is significantly associated with a decrease in exports, suggesting that these exemptions were indeed critical uses.

Ideally, measures of the difference in regulation between two countries would be interacted with some measure of MeBr intensity for the given crop in the exporting and importing countries to represent whether the commodity in question is pollution intensive or relatively clean. Unfortunately, as mentioned above, pesticide usage data is notoriously unavailable. However, since MeBr is such a broad pest management tool, California's usage might be informative as to which crops were particularly dependent on MeBr prior to the Montreal Protocol more generally. As can be seen in comparing Table 1 with Tables 3 and 4, many of those commodities with a significant negative relationship between exporter excess regulation and export quantity do coincide with MeBr's heaviest baseline users, such as tomatoes, onions, lettuces, grapes, and strawberries.

In interpreting results, some econometric issues should be kept in mind. Firstly, the estimates may be biased by the transformation of the model to a log-linear specification. Approximately 1% of observations in the data have 0 exports, all of which are dropped from the regressions, potentially introducing selection bias. More seriously, with approximately 200 countries, 50 commodities, and 25 periods, we should in theory have $49,750,000$ observations, but the COMTRADE data contains an order of magnitude fewer. While some of the difference may be attributable to genuinely missing data, the vast majority is due to the fact that most countries simply do not produce and export a given commodity, and that most countries do not trade with all other countries. Ignoring all of these "zero" export quantities may result in some loss of useful information.

Helpman et al. (2008) propse a two stage procedure to overcome these issues, involving a probit specification to determine each country's probability of exporting to a given partner followed by non-parametric estimation of conditional trade flows. This procedure is somewhat infeasible here though, as country and commodity specific characteristics would be needed to estimate a probability of trade specific to each exporter-importer-commodity triple. This would involve, for example, data on the suitability of growing conditions in each country for each crop. Alternatively, Westerlund and Wilhelmsson (2011) suggest using a fixed effects poisson maximum likelihood model to at least include the existing zeros in the data in the estimation. The poisson MLE estimates the multiplicative structure of the gravity model directly, without requiring conversion to a log-linear specification. Results from using this approach for commodity specific estimation are qualitatively similar to the OLS results, although not for all commodities. The magnitudes of the coefficients tend to be somewhat larger overall, and the standard errors are less reliable since they are cluster bootstrapped by country-pair and thus do not adequately account for the two-way non-nested structure of the data. For these reasons, the OLS estimates presented in Tables 3 and 4 are preferred.

One final important caveat to the results regardless of the specification chosen, and indeed to much of the prior PHH literature, is failure to satisfy the Stable Unit Treatment Value Assumption (SUTVA) that justifies the use of regression analysis to infer causality at all(Karp, 2011). In the context of MeBr regulation, SUTVA implies that the effect of a difference in MeBr regulation on exports between two countries is independent of differences in regulation in other country pairs. This is clearly an unreasonable assumption, particularly given that the other country-pairs may involve one of the original countries in question. Unfortunately, there is not a ready solution to this problem that enables continued use of aggregate trade data. Inclusion of additional fixed effects may go some of the way towards minimizing this problem. Importer-time fixed effects may, for example, help control for the overall extent to which countries are exporting a commodity to each importer. Further research in this area would be worthwhile.

3.5 Conclusion

The pollution haven hypothesis is as much an intuitive notion popular among environmentalists as it is a well-grounded economic proposition. Nonetheless, pollution haven effects follow naturally from the basic notion of comparative advantage and have been identified in a number of empirical studies examining the manufacturing sector. This paper adds to the existing literature by testing the PHH in an agricultural context. The international phaseout of Methyl Bromide constitutes a setting that is both novel and comparatively amenable for estimating the effects of cross-country differences in environmental regulation on trade.

Using trade data spanning the entire timeline of the MeBr phaseout at the crop level, I find strong evidence that excess exporter regulation, relative to the regulation faced by their trade partner, decreases exports. Conversely excess importer regulation tends to increase exports. The effects are generally more economically and statistically significant for crops that relied more heavily on MeBr before the phaseout began. This paper demonstrates that pollution haven effects may extend beyond the manufacturing sector, and should therefore be kept in mind during discussions of international harmonization of pesticide regulation and unilateral pesticide bans.

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