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Changes in household recycling behavior: Evidence from panel data

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ABSTRACT

This article uses a longitudinal national U.S. dataset with 232,309 pairs of same-household observations to estimate one-year or two-year changes in recycling behavior. Most households recycled at least one material, as 83% recycle paper, cans, glass, or plastic in the past year, with an average recycling rate of 2.8 materials. Recycling habits are stable, as 68% of households do not change the number of materials recycled from the previous year. Changes in county recycling are reflected in immediate changes in household behavior but at 25% of the change in the county recycling rate. Recycling rates are greater after being newly exposed to deposit laws (+7%), moving to a state with effective recycling laws (+6%), or newly available single-stream recycling (+4%). If market prices for the returned cans doubled, household recycling of cans would increase by 12%, although price responsiveness of recycling other materials is less. Shocks to the household may diminish recycling in the short term, including marriage (−2%), arrival of a newborn (−1%), and either large increase in income (−1%) or large decrease in income (−3%). The estimates for the total number of materials and which particular materials a household recycles follow similar patterns.

1. Introduction

Which household characteristics and governmental policies are most influential in altering recycling behavior? To answer this question, correlational studies such as those in the United States (Viscusi et al., 2013) and the United Kingdom (Abbott et al., 2011) can be instructive, but the causal and short-term mechanisms often are not clear. Are residents in locales with high recycling rates intrinsically high recyclers because of their pro-environmental attitudes, or would changes in locale's favorable recycling environment influence their behavior? Cross-sectional field studies do not illuminate the role of factors such as changes in the type of residence or shocks to the household structure. This article explores the insights provided by a large longitudinal dataset on U.S. households' recycling to identify the changes in the household or the recycling environment most strongly related to changes in household recycling.

The underlying economic conceptualization of the recycling decision is straightforward. Household recycling choices are broadly consistent with the household's efforts to balance the benefits and costs of recycling. Policies that boost the benefits of recycling, such as beverage container deposits, should increase recycling, as should policies that reduce recycling costs, such as recycling amenities that reduce the costs in time and effort of recycling. Personal changes that deter recycling, such as moving to an apartment where recycling opportunities to recycle are less convenient, should have the opposite relationship.

Using a large nationally representative longitudinal dataset, this article examines many of these influences. Examination of these linkages is feasible after matching to each household information on both the policy environment and the level of prices for recyclable materials to ascertain whether recycling is responsive to the economic payoff provided to communities from the sale of the recycled materials. The results are consistent with municipalities responding in the expected manner to price changes, particularly for cans and glass.

In Section 2, we describe the panel dataset and the empirical model. Information provided by respondents makes it possible to construct variables for household characteristics and place of residence. Using information on the county and state in which the household resides in each year provides the basis for matching to the household various aspects of the recycling environment, including the average county recycling rate, the presence of recycling laws, deposit policies, single-stream recycling policies, the prices of recyclable materials, and changes in the state's political environment. These variables comprise the components of the changes in the recycling regression model. Section 3 presents the estimates for changes in the total number of materials that are recycled

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using several recycling measures. Household recycling rates increase after changes that provide a more favorable recycling environment and decrease after changes that provide a less favorable environment.

The analysis of changes does not include variables such as gender, race, or age that do not change significantly over time. However, Section 3 also reports cross-sectional regressions for all variables. The cross-sectional model coefficients reflect the extent to which recycling differs across characteristics of individuals, households, counties, and states. In contrast, the analysis of changes in recycling focuses on the relationship between changes in the recycling environment and subsequent shifts in household recycling behavior. In particular, we will show that substantial changes are often disruptive, leading to negative short-term shocks that are not evident in the cross-sectional analysis.

Although some changes such as the small average changes in respondents' education level are not influential, others such as moving into an apartment can lead to a consequential shift in recycling rates. A component of our analysis that we have not seen in the existing literature is an estimate of how changes in market prices for recycled materials relate to changes in recycling rates. We also present estimates on an individual material-specific basis for paper, cans, glass, and plastic. Section 4 considers a variety of robustness tests showing stability in the main findings regardless of how the dependent variable is measured. The concluding Section 5 reviews the implications for our understanding of recycling behavior and policies that can alter recycling levels.

2. Data and empirical model

2.1. Empirical model

The focus of the empirical analysis is on the changes in the household's recycling behavior. The starting point of the model is the recycling equation in each year t. The recycling behavior variable is r_{ijt}, for household i, in state j, in period t. The vector of explanatory variables is X_{ijt}, which has a vector of coefficients given by β. The error term is u_{ijt}. The baseline regression cross-sectional equation is

$$r_{ijt} = \alpha_{0ij} + X_{ijt}\beta + u_{ijt} \ . \quad (1)$$

By focusing on the change in recycling behavior between period $t-1$ and t, the individual intercept term α_{0ij} in Eq. (1) drops out of the analysis after taking differences of the equation in year t and in year $t-1$. The first-difference recycling equation is

$$\Delta r_{ijt} = \Delta X_{ijt}\overline{\beta} + \tau_t + \Delta u_{ijt} \ , \quad (2)$$

where we explicitly note that $\overline{\beta}$ pertains to changes in the dependent variables. Eq. (2) also includes year fixed effects, τ_t. Although technically year effects drop out of the analysis after first differencing, time-specific factors not otherwise accounted for in the model should be considered since the sample includes households experiencing changes in recycling that occurred in different time periods. First differencing also nets out the household-specific constant term. More important is that it also nets out the household-specific component of the error from the error term. The household-specific error component may be correlated with recycling equation variables, leading to potential bias in the estimates of policy impacts. In addition to using $\overline{\beta}$ to account for analyzing changes in recycling in a single period from $t-1$ to t, we also consider wider differences of two years.

Note that the changes coefficient $\overline{\beta}$ has a different meaning from the static coefficient. The changes analysis indicates the short-term (one or two year) shift in recycling for a given household, while the static analysis reflects the association between recycling and household characteristics or legal regimes. Not all the changes experienced by the household are smooth or involve only marginal impacts. Consequently, $\overline{\beta}$ sometimes pertains to the relationship between shocks to the household and changes in recycling rates recycling. In contrast, the static β of Eq. (1) reflects correlations that that characterize how households have adapted their recycling behavior based on their resources as well as social and legal environments. Although the article focuses on changes in recycling behavior, we also present the static cross-sectional estimates of the main equation for comparison.

2.2. Data and sample characteristics

The U.S. recycling dataset used for this study is from the Knowledge Networks-GfK KnowledgePanel from 2005 to 2014. Recycling behavior during this time period does not differ substantially from that in the post-survey period to the time of this analysis. Fig. 1 illustrates the trends in the percent tonnage of each material that is recycled from 2005 to 2018.[1]

In the years 2015 to 2018, which is after the time period for our sample data, the percentage of the recycled material changed by 1% for paper, 0% for metal and plastic, and − 3% for glass. This stability shown in the U.S. Environmental Protection Agency (EPA) data suggests that the survey results have not been overtaken by any subsequent extreme events.

To generate a nationally representative Web-based panel, Knowledge Networks adopted a probability-based sampling approach, providing internet access to those that lacked such a capability. A routine task for panel members is to complete a broad profile survey. Included as a minor part of that survey is a set of four questions about the household's recycling behavior. The authors and various organizations have also run surveys using samples drawn from this panel, usually at a cost of $50 per completed interview. These focused efforts gave panel members an opportunity to take surveys on particular topics, as in a plastic water bottle recycling article by Viscusi et al. (2012). Since panel members must agree to complete such specific surveys, a general concern is that the selection process may affect the sample composition, or that specifying the survey topic could potentially bias the estimates. Instead, this article relies on the profile interviews that all panel members complete, thus limiting potential bias due to self-selection. It also covers a broad range of topics, which eliminates a potential focus compared to a single survey only concerned with recycling. An additional strength of the data is that the KnowledgePanel is a broadly representative national sample and is the "oldest and largest probability-based panel in the U.S."[2] Previous recycling studies using data from this panel have been cross-sectional studies (e.g., Viscusi et al., 2013) or have been restricted to a subsample of households that moved between states (Viscusi et al., 2020).

The sample consists of 82,098 unique households that participated in at least two panel surveys. The dataset for this analysis is restricted to the analysis of changes in recycling, for which there are observations in the base year and the year of the next panel survey. There are 232,309 observations pertaining to a pair of years for which data are available in the base year and a subsequent year. Table 1 presents the summary characteristics of the sample.

For some households, there is information on multiple pairs of surveys, and the statistical analysis will account for such multiple observations for any household. On average, each household appears in the sample in just under three survey pairs. The time between surveys for

[1] These data were calculated from EPA's National Overview: Facts and Figures on Materials, Wastes and Recycling, available at https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials

[2] For a description of the current panel, see https://www.ipsos.com/en-us/solutions/public-affairs/knowledgepanel. Organizations that have used the panel include the Urban Institute Well-Being and Basic Needs Survey, the Kennedy Institute of Politics Youth and Politics Surveys, and the Pew Research Center American Trends Panel. The authors also used the panel for surveys for the U.S. Environmental Protection Agency that were approved by the U.S. Office of Management and Budget Office of Information and Regulatory Affairs.

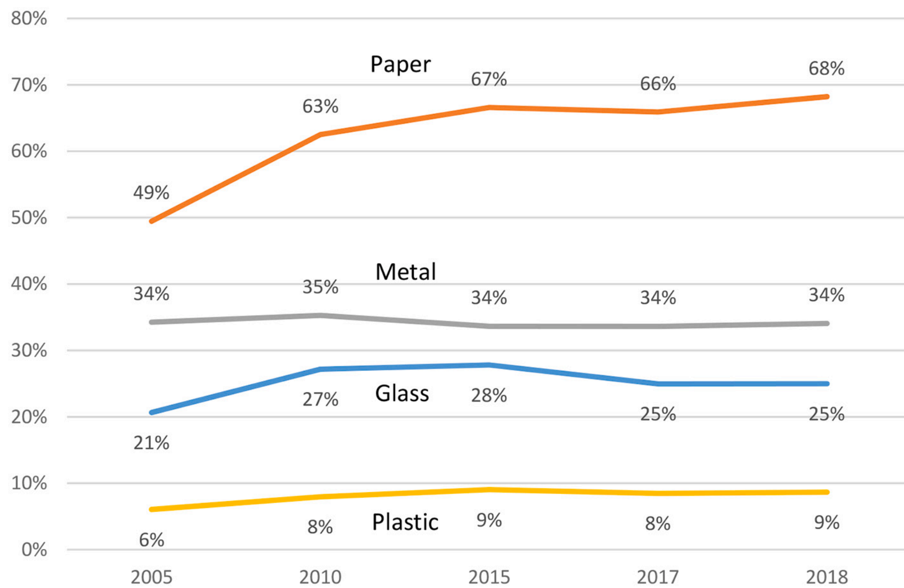

Fig. 1. Percent of Municipal Solid Waste Diverted to Reycling, by Material, 2005–2018.

Table 1
Sample Characteristics.

Variable	Mean	Std.Dev.
Total materials recycled (0–4)	2.79	1.56
County total materials recycled	2.76	0.77
Recycled Paper	0.70	0.46
Recycled Cans	0.76	0.43
Recycled Glass	0.62	0.49
Recycled Plastic	0.71	0.45
Single-stream	0.27	0.44
Single-stream (where data available)	0.59	0.49
Deposit law in state	0.29	0.45
Effective recycling laws (mandatory, opportunity, plan)	0.81	0.39
Paper price per pound	0.04	0.01
Cans price per pound	0.75	0.10
Glass price per pound	0.01	0.003
Plastic price per pound	0.23	0.05
Income (/ $10 k)	6.78	4.36
Top income category ($175 k+)	0.04	0.19
Apartment	0.17	0.37
House	0.82	0.38
Unemployed	0.06	0.24
Retired	0.23	0.42
Age	52.02	15.69
Female	0.60	0.49
Race: White	0.83	0.38
Ethnicity: Hispanic	0.09	0.29
Years of education	14.74	2.56
Homeowner	0.79	0.41
Married	0.67	0.47
Household size	2.67	1.45
Infant in the home (age 1 or less)	0.03	0.18
Democrat	0.52	0.50
Democratic state legislature	0.44	0.50
Republican state legislature	0.42	0.49
Landfill tipping fee, 2013 ($/ton)	49.64	16.14
Time since previous survey, in years	1.20	0.40
Missing data, single-stream	0.55	0.50
Missing data, county recycling	0.01	0.10

each survey pair is either one or two years. There are 185,130 observations with a one-year span between surveys, and 47,179 with a gap of two years between surveys.

The block of recycling questions included in the profile survey consists of whether the household reports recycling each of the following four materials in the past year:

Paper: "In the past 12 months, have you recycled your newspapers or other papers?"
Cans: "In the past 12 months, have you recycled your cans?"
Glass: "In the past 12 months, have you recycled your glass?"
Plastic: "In the past 12 months, have you recycled your plastic?"

These questions do not verify that the household has actually recycled these materials, nor does the survey ascertain the amount of each material that is recycled. These self-reported measures are nevertheless instructive in that they are strongly correlated with the tonnage of materials that are recycled. Bell et al. (2017) found that in Wisconsin, the elasticity of the tonnage of materials recycled in the household's county with respect to the number of materials that the household reports recycling in the KnowledgePanel survey data is 0.82 (S.E. 0.24). This point estimate implies that there is nearly a unitary relationship between reported recycling and tonnage, i.e., a 10% increase in the average reported number of materials recycled leads to an 8% increase in tonnage. It is not possible to reject the hypothesis that actual tonnage of recycled materials is directly proportional to the number of recycled materials indicated in the survey responses.

The households in the sample have an average income of just under $68,000. The sample consisted of 6% who are *unemployed*. Information on whether the respondent is *married*, *divorced*, *widowed*, or has an *infant in the home* is also included, as are measures of *years of education*,[3] and *household size*. Overall, 79% of the sample own their residence, which we designate as *homeowner*. Four-fifths of the sample live in a house and one-sixth of the sample live in an *apartment*.

Recycling behavior was fairly stable over time. Among households with a one-year period between surveys, 68% indicated no change in the number of materials that were recycled compared to the previous survey. Changes in behavior were evenly distributed between increases and decreases in the recycling amount from the previous year. For the full sample of one-year and two-year periods between surveys, 10% of the respondents recycled one more material and 10% recycled one less material, 3% recycled two more materials and 3% recycled two fewer materials, 2% recycled three more materials or three fewer materials,

[3] Years of education is coded in number of years (0–20) according to the categories in the profile survey: no formal education, 1-4th grade, 5–6, 7–8, 9, 10, 11, 12 without diploma, high school or GED, some college, associate degree, bachelors, masters, professional or doctorate.

and just under 2% recycled four more materials or four fewer materials.

Political control of state legislature is indicated by *Democratic state legislature* or *Republican state legislature*, which do not sum to 1 because some states have split party control between state house and state senate. The political information about respondents included in the survey is based on which of the following political identifications the respondent believed best described them:

Strong Republican
Not Strong Republican
Leans Republican
Undecided / Independent / Other
Leans Democrat
Not Strong Democrat
Strong Democrat

Respondents were identified as Democrats in a particular year if they responded as one of the three Democratic categories.

Table 2 describes the changes in respondent, household, and state characteristics between surveys.

The patterns indicate the stability of recycling practices over time for each of the four particular materials. The coding of the columns indicates whether the respondent started recycling the material, continued to recycle the material as before, or stopped recycling the material. Thus, 85% of the sample reporting recycling or not recycling any individual material in the base year continued that habit in the subsequent period. The percentages for those who began to recycle the material or who stopped recycling the material are evenly distributed and are in the 7% to 8% range for changes in each direction.

The measures of the changes in the household characteristics and recycling environment variables shown in Table 2 indicate greater stability than the changes in recycling measures. The change variables in Table 2 pertain to whether the respondent took on the status specified by the variable (e.g., became *unemployed*), exhibited no change with respect to the variable, or moved out of being included in this category (e.g., became no longer *unemployed*). The income change variables are defined with respect to a large change in income. The *income up* variable is an indicator for whether the household experienced a 20% or more income increase, which 8% of the sample did, and the *income down* variable represents a 20% or more income decrease, as was experienced by 4% of the sample.

There are two political variables pertaining to the political preferences of the respondent and the state. Ideology and political preferences can influence the assessment of the societal benefits of recycling both from the standpoint of the household as well as the preferences of their political representatives (Coffee and Joseph, 2013). The household-specific measures are whether the respondent became, stopped, or had no change about whether they are a Democrat.

Table 2
Distribution of Year-to-Year Changes in Respondent Characteristics.

Change Variable	Started = 1	NoChange = 0	Stopped = −1
	%	%	%
Paper recycled	7.32	85.04	7.64
Cans recycled	7.13	85.22	7.64
Glass recycled	7.58	85.26	7.16
Plastic recycled	7.50	85.43	7.07
Single-stream	3.34	96.62	0.04
Deposit law in state	0.17	99.59	0.24
Effective Recycling laws	0.09	99.80	0.11
Income up 20% or more	7.93	92.07	–
Income down 20% or more	4.47	95.53	–
Apartment	2.53	95.49	1.99
Unemployed	2.25	95.28	2.47
Retired	2.45	97.55	–
Homeowner	2.47	95.46	2.07
Newly married	2.10	97.90	–
Household size	7.38	85.37	7.26
Infant in the home (age 1 or less)	3.18	96.82	–
Years of education	4.76	95.24	–
Democrat	2.55	94.88	2.56
Democratic legislature	5.78	90.97	3.25
Republican legislature	5.26	88.60	6.13

The state political variables are for whether the legislature became majority Democratic in the past two years, exhibited no change in Democratic control, or stopped being majority Democratic, and an analogous variable for Republican control of legislatures. The political control of state legislatures is based on information from the National Conference of State Legislatures.[4]

The recycling measures considered in Section 3 will span four types of materials (paper, cans, glass, and plastic). On average, respondents recycled 2.79 different materials. A large majority of households recycled at least one material over the past year. The probabilities of households recycling particular materials during the past year range from 62% for glass to 76% for cans.[5] Using the full set of 383,571 observations, not simply those for which there are longitudinal data on changes, we also constructed a measure of the average county recycling rate.

The county recycling measure will be an explanatory variable to reflect local area changes in amenities that encourage recycling and shifts in recycling by neighbors in the county. The construction of this variable excluded the respondent's own recycling behavior from the calculation. The county average of 2.76 materials recycled is similar to the overall sample average of 2.79. County recycling rates will embody two types of influences. Positive shifts in county recycling rates may be highly correlated with changes in recycling amenities that facilitate recycling. Seeing higher levels of county recycling also may reinforce recycling as a social norm, thus encouraging recycling behavior. Several articles have indicated a prominent role of social norms as a determinant of recycling behavior (Halvorsen, 2008; Viscusi et al., 2011; Abbott et al., 2013; Gilli et al., 2018; Huber et al., 2018; Czajkowski et al., 2019). The empirical analysis will estimate the relationship between changes in the county recycling rate and changes in the household's recycling behavior, but it cannot distinguish the relative influence of factors such as amenities and norms that are embodied in the county recycling variable.

2.3. Prices

The prices that municipalities receive for the recycled materials may influence the degree to which recycling efforts are supported. The financial return that municipalities can reap from recyclable materials can provide an inducement to promote recycling as a revenue source, and the resources obtained by selling the recycled materials may enable the municipality to promote household recycling efforts. Whether recycling is a net economic benefit to the municipality and to society has been a continuing issue in the literature (Aadland and Caplan, 2006; Kinnaman, 2006, 2014; and Bell et al., 2017). While it is unlikely that households will know whether materials prices have changed or will care about such changes even if they are aware of them, they should respond to the changes in recycling amenities and practices that are influenced by price changes. To the best of our knowledge, there has been no study of how the prices of recyclable materials are associated with household recycling rates using a national sample.

The materials price variables we use are continuous measures of the single-year change in materials prices, i.e., *price change from previous year*. This variable was constructed based on the respondent's state of

[4] http://www.ncsl.org/documents/statevote/legiscontrol_2002_2014.pdf

[5] These numbers differ from Figure 1 because they consider only household reporting of recycling, do not measure the volume recycled, and do not consider the behavior of non-household actors such as restaurants or other businesses.

residence coupled with annual materials prices per pound for each of paper, cans, glass, and plastic. The annual price information used data compiled by http://RecyclingMarkets.net and uses six different regions to show how prices vary across the United States. Because of the differences in the absolute levels of price per pound across the different materials, Fig. 2 illustrates the temporal trajectory of price changes.

While the materials prices are each similar in 2014 to their 2005 starting points, there is a great deal of fluctuation in both directions during the survey period, leading to average annual price increases for the sample of 13% for paper, 2% for cans, 6% for glass, and 10% for plastic. When there was a change in either direction, those fluctuations in prices are much greater than the more modest average price change. For observations with a positive increase in prices, the percentage increase is 72% for paper, 17% for cans, 24% for glass, and 33% for plastic. The percent changes conditional on a price decrease are 27% for paper, 16% for cans, 25% for glass, and 22% for plastic. There also is variation in price changes across different regions, as reflected by the size of standard deviations of the price changes shown in Table 1. Comparable standard deviations are exhibited for the specific product prices on a yearly basis as well.

2.4. Policies: laws, deposits, and single-stream recycling

Information on the household's county and state of residence is particularly useful in constructing measures for the recycling environment. The two types of state laws that are considered are deposit laws and the general categories of recycling laws.

Fig. 3 shows the geographical distribution of these statutes. The first such variable is whether the state has a deposit policy for beverage containers, which we designate by *deposit* and is indicated using black stripes. There are 11 states with beverage deposit laws, including all states in the northeast except New Hampshire. In addition to specifying a deposit amount, which is usually 5 cents per container, deposit laws also specify the procedures for returning the container and the refund infrastructure. Deposit policies provide a financial inducement to recycle and often serve as an income source for lower-income groups (Ashenmiller, 2009, 2010, 2011). Deposits are perhaps the most prominent example of using pricing mechanisms to boost recycling, but there are other financial mechanisms that could be used to incentivize recycling such as weight-based billing for non-recycled waste (Reschovsky and Stone, 1994; Fullerton and Kinnaman, 1996; Hong and Adams, 1999; Van Houtven and Morris, 1999; Kinnaman and Fullerton, 2000; Jenkins et al., 2003; Bohara et al., 2007; Bel and Gradus, 2016).

The scope of the laws differs, in that five states also have deposit policies for plastic water bottles. For example, Connecticut and Oregon adopted deposit policies for plastic water bottles in 2009 so that there is within-state variation in the presence of such deposits rather than having to rely on estimates based only on those who have newly gone into a deposit regime after an interstate move. However, empirical estimates using these data did not indicate a statistically significant premium in recycling plastic in states that also had deposits for water bottles. Our plastic recycling measure is for all plastic materials, not just plastic water bottles, thus leading to likely understatement of water bottle deposits' relationship to recycling. The targeted survey by Viscusi et al. (2012) included a question on the recycling of plastic water bottles, which did respond in the expected direction after the advent of deposits for plastic water bottles.

General statewide recycling laws are more prevalent than deposit policies. The empirical measure for strong recycling laws is a 0–1 variable, *recycling laws,* for whether the state has statutes that make recycling mandatory, require municipalities to provide recycling opportunities, or require that municipalities have a recycling plan. States with no recycling laws or have laws which only specify an aspirational recycling goal are coded as zero, following the statutory hierarchy in Viscusi et al. (2013). As indicated by the shaded states in Fig. 3, thirty states have recycling laws that require some action, with the principal exceptions being states that are in the middle of the country. Although the dataset does not include information on whether the household has local amenities such as curbside recycling, the presence of the state statutory requirements is strongly related to specific recycling amenities. Curbside recycling has played a prominent role in the literature (Aadland and Caplan, 2006; Abbott et al., 2017; Best and Kneip, 2019) and is correlated with these recycling laws. Curbside recycling is only available for 43% of the household in states with no laws and 25% of the households with recycling goal laws, but curbside recycling is available for 64% of households with recycling plans, 76% of households with opportunity to recycle laws, and 86% for households with mandatory recycling laws (Viscusi et al., 2012). The average county recycling rate variable in the regressions also accounts for differences across counties in the recycling environment.

Although it is not a general statutory requirement, an additional policy intervention for which we have data is the provision of single-stream recycling so that households do not have to separate their recyclable materials. Single-stream recycling options facilitate recycling and are economically desirable despite the contamination of other recyclables with broken glass (Oskamp et al., 1996; Bell et al., 2017). For about half of the sample, we have information by county on whether single-stream recycling is available. The analysis includes a missing data indicator for observations lacking the single-stream information. Based on available information on single-stream recycling, one-fourth of the sample has access to single-stream recycling or about half of all respondents for which the status of single-stream recycling is known.

For many households, the state laws, deposit requirements, the political control of the state legislature, and the single-stream recycling option did not differ across households. Our sample includes a number of households (3704) who moved to a different state or county and thereby may have experienced a change in those laws and amenities.

3. Changes in the number of materials recycled

3.1. Core regression results

The core regression results based on Eq. (2) above utilize a sample consisting of all observed changes in recycling behavior using as the dependent variable the change in the number of materials that are recycled between the current survey and the previous survey. The dependent variable consequently takes on an integer value from −4 to +4, and the coefficients reflect the change in the number of materials associated with that coefficient. Subsequent sections explore variations on the estimates for changes in the materials recycled using different samples and different specifications of the dependent variable. For comparison, we also report the core regression results based on the cross-sectional model in Eq. (1) above, where the dependent variable is a count of the number of materials recycled at the time of the second survey in the pair. The independent variables in the cross-sectional model are the current household and community characteristics in the household's second survey.

Table 3 reports the key coefficients for both the changes model and the cross-sectional model. The first column of Table 3 estimates the change in the number of materials recycled between the first and second survey of a pair, as indicated by Eq. (2) above. The second column of Table 3 presents the cross-sectional estimates of Eq. (1) above. The dependent variable in the cross-sectional model is the number of materials a household recycled in the second year of the survey pair in the longitudinal sample, which is then regressed on the characteristics at the time of the second survey. Because a household in both analyses may appear in the sample with more than one survey pair, standard errors are clustered by individual household.

Many of the variables reflecting the recycling policy environment are statistically significant with signs in the expected direction. Changes in the county recycling rate embody improvements in local recycling amenities as well as the prevalence of recycling norms. However, for the

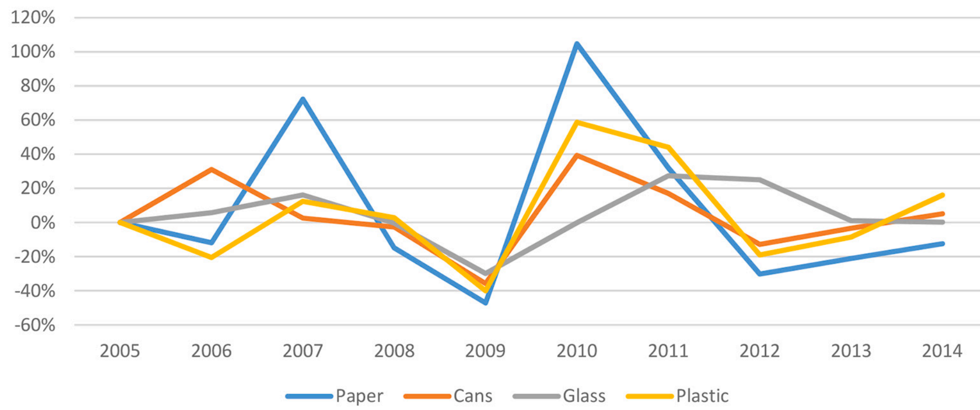

Fig. 2. Materials Prices, Percent Changes by Year.

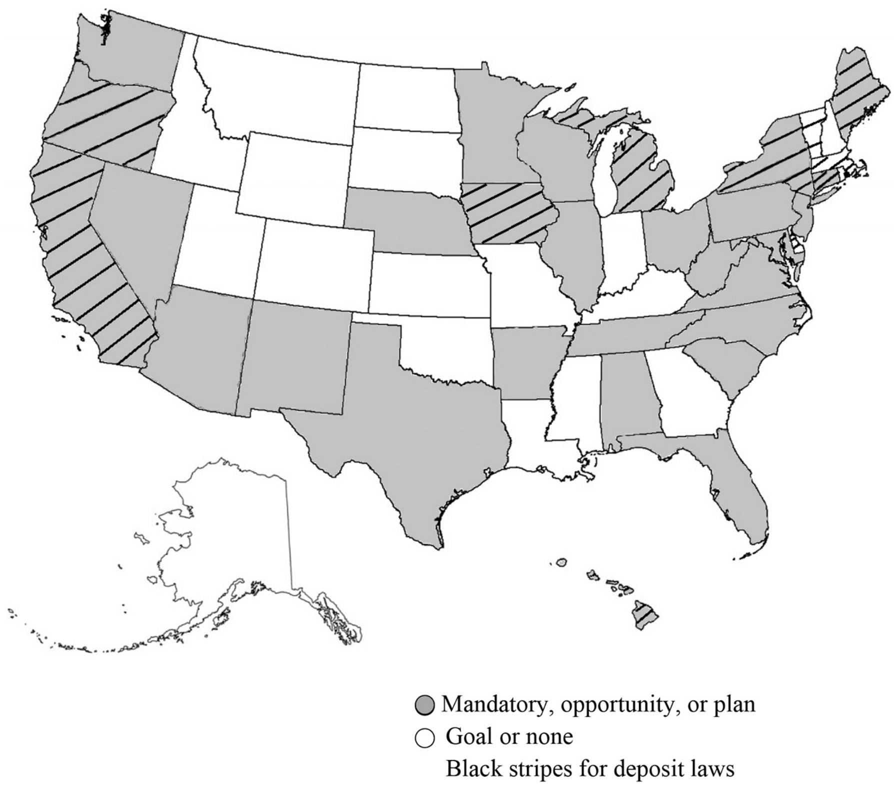

Fig. 3. Distribution by Stringency of State Recycling and Deposit Laws.

correlational results in column 2, the expected level of recycling for the household tracks very closely to the actual county level.

The three recycling policy variables in Table 3 are for deposit laws, effective recycling laws, and single-stream recycling. There is an increase in the number of materials that are recycled of 0.19, or 7% of the 2.79 materials recycled, after the advent of a deposit law. Moving into a state with an effective recycling law has a comparable coefficient of 0.18, which reflects a 6% increase in recycling rates. Changes in recycling after a change in the single-stream recycling environment indicate that the net relationship of recycling to the availability of single-stream recycling is positive, but the number recycled only increases by 0.10 materials after the introduction of single-stream recycling, a 4% increase. The single-stream recycling variable is not statistically significant in the cross-sectional analysis, but the other two recycling law variables are statistically significant. Although the inclusion of the county recycling rate in the equation may capture some of the impact of the recycling policy variables, exclusion of the county recycling variable does not affect the statistical significance of the law and deposit variables and the magnitudes of the coefficients are similar.[6]

Next consider the role of prices of recycled paper, plastic, cans, and glass. The degree to which municipalities promote recycling should depend on the financial return received for the recycled materials. The change in the region's price of cans and the price of glass are each strongly statistically significant positive predictors of the number of recycled materials. The average price per pound for cans during the survey period was $0.75. A doubling of that price would be associated with an increase in recycling by 0.33 materials, or 12%. Glass prices were a much smaller $0.01 per pound, so that the change in recycling

[6] The largest change is for single-stream recycling, which increases from 0.1078 to 0.1372 if the county recycling change is omitted. The coefficients for deposit and recycling laws change by less than 0.01.

Table 3
Regressions Predicting Changes in Materials Recycled (−4 to 4) and Number of Materials Recycled (0 to 4).

Changes (Column 1) or Level (Column 2)	Changes in Within-Household Recycling	Cross Section across Households
County total materials recycled	0.2497***	0.8834***
	(0.0066)	(0.0063)
Single-stream	0.1078***	−0.0019
	(0.0139)	(0.0129)
Deposit law in state	0.1872***	0.0357***
	(0.0462)	(0.0129)
Effective recycling laws	0.1808**	0.0615***
	(0.0750)	(0.0131)
Paper price per pound	−0.1019	2.4708**
	(0.7503)	(1.0483)
Cans price per pound	0.4427***	−0.0925
	(0.1645)	(0.1953)
Glass price per pound	3.1616**	−0.9404
	(1.4756)	(1.8153)
Plastic price per pound	0.2523	0.8879**
	(0.2628)	(0.4124)
Income (/ $10 k)		0.0257***
		(0.0013)
Top income category ($175 k+)		−0.1836***
		(0.0212)
Income increase larger than 20%	−0.0248***	
	(0.0096)	
Income decrease larger than 20%	−0.0752***	
	(0.0129)	
Apartment	−0.0606***	−0.3605***
	(0.0144)	(0.0139)
Unemployed	0.0373***	−0.0182
	(0.0134)	(0.0156)
Retired	0.0235*	0.0133
	(0.0140)	(0.0126)
Homeowner	0.0019	0.2000***
	(0.0143)	(0.0130)
Married, yes	−0.0447**	0.0992***
	(0.0202)	(0.0105)
Household size	0.0080	−0.0019
	(0.0070)	(0.0035)
Infant in the home (age 1 or less)	−0.0393***	−0.0361*
	(0.0139)	(0.0200)
Years of education	−0.0178	0.0760***
	(0.0126)	(0.0019)
Democrat	−0.0041	0.1147***
	(0.0119)	(0.0089)
Legislature recently (2 yr) Democrat	−0.0003	0.0162
	(0.0053)	(0.0124)
Legislature recently (2 yr) Republican	−0.0213***	0.0223*
	(0.0050)	(0.0132)
Age		0.0079***
		(0.0004)
Female		0.1284***
		(0.0095)
Race: White		0.3193***
		(0.0127)
Ethnicity, Hispanic		0.0209
		(0.0165)
Landfill tipping fee, 2013		0.0019***
		(0.0004)

Notes: $N = 232{,}309$. Robust standard errors in parenthesis, clustered by 82,098 households. OLS regressions also included year-fixed effects and indicator variables for whether single-stream or county data were missing, whether the time between surveys was one or two years, and a constant term. *significant at 10%; **significant at 5%; ***significant at 1%.

after doubling the price is only 0.03 materials, which is a bit over 1%. The other price change variables are not statistically significant. To the extent that municipalities' policies and consumer decisions are related to recycling generally, the role of prices may not be restricted to the particular material experiencing a price change. A municipality conceivably could encourage more recycling of glass containers in response to an increase in glass prices, but its policy tools may be blunt and have a more broadly-based impact if it is not feasible to have targeted changes in recycling by material.

Although more affluent households tend to recycle to a greater extent based on the estimates in column 2, large short-term changes in income have somewhat different outcomes, perhaps because they disrupt the household's recycling routine. The changes analysis shows negative changes in the number of materials recycled for either a 20% or more drop in income or a 20% or more increase in income. However, the magnitude of these relationships is modest, with a drop of 0.02 materials after income increases and a drop of 0.08 materials after income decreases. In the short run, the added effort required to cope with a large shift in income may work against the generally positive cross-sectional effects of income. Section 4.3, which considers one-year and two-year spans between surveys separately supports this idea of a shock, where recycling changes after income decreases are larger in the two-year subsample, while the recycling changes after income increases are no longer significant in that subsample. If the observed changes in recycling were due to changes in the opportunity cost of time alone, then decreases in income might facilitate recycling if the income decrease were due to fewer hours worked by the household. That impact of available time is borne out in the positive coefficient for the *unemployed* variable, as respondents who became unemployed have recycling rates that are 0.04 materials greater.

The convenience and time costs of recycling will also depend on the household structure and the place of residence. Getting married is negatively related to changes in recycling despite a positive long-term association with marriage in the cross-section analysis. Having an infant one year old or less has comparable negative coefficients in both analyses. Moving into an apartment from a house creates fewer opportunities for recycling and is associated with a decrease in the number of recycled materials of −0.06, which is consistent with the lower recycling rates in multi-family dwellings (Abbott et al., 2013). Becoming a homeowner does not have a statistically significant coefficient in the changes analysis, but it is positively associated in the long run as the benefits of ownership emerge. Other variables such as shifts in *years of education*, and in the respondent's political orientation are not statistically significant in the changes analysis but are strongly positive in the cross-sectional analysis. Generally, the near-term impacts of substantial personal changes generate duties and responsibilities that can reduce the otherwise positive recycling relationships.

The political composition of the state government also may affect the availability and quality of recycling amenities. Changes in the political majority in the legislature are associated with a statistically significant short-term drop of 0.02 materials recycled when there is newly Republican control, but no corresponding relationship with that statistical power is observed when legislatures become Democratic. The magnitudes of the coefficients are small, so that it is the aforementioned policy interventions rather than political control per se that are most important.

3.2. Core regression results by material

Table 4 presents the changes regressions for the binary changes in the recycling of paper, cans, glass, and plastic. The recycling rate for all materials is relatively high, though the 62% rate for glass is below the rates of 70% for paper, 71% for plastic, and 76% for cans. To the extent that households tend to bring all of their recyclable materials to a curbside location or a recycling center, one would expect the regression results to be similar for all variables. The main possible exception of interest is that changes in the market price for each of the materials can induce changes in the recycling of the affected material by different amounts.

The policy measures perform generally as found in the regressions in Table 3 for the change in recycling each of the materials. The *county recycling* rate variables have comparable coefficients of 0.02 for each of

Table 4
Regressions Predicting Changes in Individual Materials Recycled (−1, 0, +1).

Changes in: On recycling of	Paper	Cans	Glass	Plastic
County total materials recycled	0.2041***	0.2153***	0.2011***	0.2156***
	(0.0070)	(0.0073)	(0.0070)	(0.0069)
Single-stream	0.0260***	0.0245***	0.0322***	0.0346***
	(0.0047)	(0.0046)	(0.0047)	(0.0047)
Deposit law in state	0.0177	0.0542***	0.0533***	0.0591***
	(0.0148)	(0.0145)	(0.0155)	(0.0140)
Effective recycling laws	0.0330	0.0510**	0.0450*	0.0592**
	(0.0236)	(0.0227)	(0.0235)	(0.0234)
Price change from previous year	0.1514	0.1184**	0.1371	0.1401
	(0.2599)	(0.0526)	(0.4826)	(0.0886)
Income increase larger than 20%	−0.0056*	−0.0082**	−0.0037	−0.0077**
	(0.0033)	(0.0033)	(0.0033)	(0.0033)
Income decrease larger than 20%	−0.0178***	−0.0172***	−0.0210***	−0.0202***
	(0.0043)	(0.0043)	(0.0043)	(0.0043)
Apartment	−0.0159***	−0.0157***	−0.0139***	−0.0143***
	(0.0049)	(0.0049)	(0.0048)	(0.0049)
Unemployed	0.0111**	0.0101**	0.0054	0.0096**
	(0.0045)	(0.0045)	(0.0045)	(0.0044)
Retired	0.0073	0.0065	0.0067	0.0062
	(0.0049)	(0.0049)	(0.0050)	(0.0051)
Homeowner	0.0032	0.0030	0.0017	−0.0044
	(0.0049)	(0.0048)	(0.0048)	(0.0048)
Married, yes	−0.0164**	−0.0081	−0.0094	−0.0121*
	(0.0068)	(0.0067)	(0.0065)	(0.0064)
Household size	0.0021	0.0044*	0.0002	0.0010
	(0.0024)	(0.0024)	(0.0024)	(0.0024)
Infant in home (age 1 or less)	−0.0020	−0.0167***	−0.0021	−0.0185***
	(0.0047)	(0.0046)	(0.0046)	(0.0046)
Years of education	−0.0037	−0.0073*	−0.0021	−0.0048
	(0.0043)	(0.0043)	(0.0042)	(0.0042)
Democrat	−0.0015	−0.0017	−0.0014	0.0010
	(0.0040)	(0.0041)	(0.0040)	(0.0040)
Legislature recently (2 yr) Democrat	0.0016	0.0001	0.0001	−0.0026
	(0.0018)	(0.0017)	(0.0018)	(0.0017)
Legislature recently (2 yr) Republican	−0.0048***	−0.0071***	−0.0026	−0.0050***
	(0.0017)	(0.0017)	(0.0016)	(0.0017)

Notes: N = 232,309. Robust standard errors in parenthesis, clustered by 82,098 households. OLS regressions also included year-fixed effects and indicator variables for whether single-stream or county data were missing, whether the time between surveys was one or two years, and a constant term. *significant at 10%; **significant at 5%; ***significant at 1%.

the four materials, with coefficients about 0.03 for the *single-stream* variable. The *deposit* change variable functions as expected given that deposits are product-specific. Beverage container deposits are not statistically significant for paper recycling but are statistically significant predictors of the probability of recycling cans, glass, and plastic, reflecting a 0.05 to 0.06 increase in the probability that these materials are recycled. In these regression results, there is no apparent spillover benefit on paper recycling from changes to deposits for recycled metals, glass, or plastic.

Unlike the estimates in Table 3, in which changes in all four price variables potentially affect the entire set of recyclable materials, Table 4 shows that recycling differs by material. A price increase is a statistically significant predictor of the recycling of cans, as a doubling of the price of recycled cans is associated with a 9% increase the probability that the household recycles cans. Coefficients for price changes of the other three materials are not statistically significant.

The most noteworthy household characteristic variables are the statistically significant negative coefficients for *legislature recently Republican*, for each material except glass, the 0.02 lower probability of recycling each of these materials if the household has experienced a 20% drop in income, and the significant role of moving into an apartment. Having a new infant in the household is negatively related to recycling cans and plastic.

4. Robustness tests

4.1. Regressions for directions of change in recycling

In addition to our main results measuring recycling change as a continuous variable between +4 and − 4 to measure changes in the recycling of all four materials, we also considered simple directional changes where the recycling variable is −1 if the change in the total number of materials recycled decreases, 0 if there is no change, and it is +1 if it increases. As in the case of column 1 of Table 3, the explanatory variables all consist of changes in those measures. Column 1 of Table 5 reports the marginal effects from ordered logit estimates of the changes in recycling behavior based on the direction of the number of materials that are recycled, while column 2 of Table 5 reports the ordered logit counterpart of the equation in Table 3.

For the changes analysis in column 1 of Table 5, the county recycling variable has a marginal effect of 0.06 for a one unit change of the county recycling rate. This variable continues to have the largest coefficient of the policy-related variables. The three discrete policy variables are positive and remain strongly statistically significant. The marginal effects are 0.03 for single-stream recycling, 0.03 for deposit laws, and 0.04 for effective recycling laws.

Price change variables are statistically significant for cans and glass, as in the case of Table 3. Evaluated at the mean level of prices, the estimates for cans correspond to a marginal effect of 0.08, and the estimates for glass correspond to a marginal effect of 0.01. The other coefficients are also largely in line with the earlier results in terms of direction and significance.

The second column of coefficient estimates in Table 5 reports the marginal effects for the ordered logit estimates of the number of materials that are recycled using the −4 to +4 range. This regression is the ordered logit counterpart of the regression in column one of Table 3. The rationale for considering these estimates is that the recycling measure may reflect the intensity of recycling rather than the exact count of the number of materials that are recycled. The policy-related variables continue to be strongly significant. The price change variables for cans and glass also are statistically significant.

4.2. Recycling at the extremes

The regressions thus far have examined different gradations of recycling concerning the number of materials that are recycled. In this section, we focus on the two extremes. At the low end, we identify the variables that are correlated with the threshold decision of whether to recycle at all. This initial decision of whether to become a recycler is often important in that once a household chooses to start recycling tends to generate recycling in the future (Viscusi et al., 2013). At the opposite extreme, we identify the variables that push the household into recycling all four materials rather than being selective among materials recycled. Some variables may not be influential at the extremes but do play a role in influencing the intermediate quantities of recycled materials so that the differences with the previous results are of independent interest.

The first measure considered is column 1 of Table 6, for whether the respondent recycles any material. Thus, it takes on a value of 1 if the respondent shifts from no materials to any nonzero amount, a value of 0 if the respondent doesn't change status in terms of being a recycler or a non-recycler, and a value of −1 if the household stops being a recycler altogether.

The variable for changes in recycling all four materials shown in the second set of regression results in Table 6 has a value of 1 if the

Table 5
Ordered Logit Regressions of the Change in the Number of Materials Recycled.

Changes in	Coefficient (−1 / 0 / +1)	Coefficient (−4 to + 4)
County total materials recycled	0.05772 ***	0.00674 ***
	(0.00166)	(0.00021)
Single-stream	0.02171 ***	0.00268 ***
	(0.00334)	(0.00038)
Deposit law in state	0.03215 ***	0.00419 ***
	(0.01040)	(0.00125)
Effective recycling laws	0.03986 **	0.00508 **
	(0.01698)	(0.00208)
Paper price per pound	−0.00390	−0.00084
	(0.19308)	(0.02162)
Cans price per pound	0.11222 ***	0.01304 ***
	(0.04218)	(0.00470)
Glass price per pound	0.90970 **	0.10309 **
	(0.37699)	(0.04205)
Plastic price per pound	−0.00878	0.00096
	(0.06736)	(0.00753)
Income increase larger than 20%	−0.00557 **	−0.00066 **
	(0.00250)	(0.00029)
Income decrease larger than 20%	−0.01837 ***	−0.00223 ***
	(0.00338)	(0.00041)
Apartment	−0.01267 ***	−0.00153 ***
	(0.00359)	(0.00041)
Unemployed	0.00783 **	0.00096 **
	(0.00328)	(0.00038)
Retired	0.00119	0.00026
	(0.00362)	(0.00040)
Homeowner	−0.00052	−0.00003
	(0.00355)	(0.00041)
Married, yes	−0.01123 **	−0.00135 **
	(0.00511)	(0.00061)
Household size	0.00295 *	0.00033 *
	(0.00172)	(0.00020)
Infant in home (age 1 or less)	−0.00598 *	−0.00081 **
	(0.00352)	(0.00041)
Years of education	−0.00325	−0.00042
	(0.00319)	(0.00037)
Democrat	−8.77e-6	−0.00002
	(0.00292)	(0.00033)
Legislature recently (2 yr) Democrat	−0.00129	−0.00012
	(0.00133)	(0.00015)
Legislature recently (2 yr) Republican	−0.00639 ***	−0.00072 ***
	(0.00133)	(0.00015)

Notes: N = 232,309. Marginal effects reported. Robust standard errors in parenthesis, clustered by 82,098 households. Ordered logit regressions also included year-fixed effects and indicator variables for whether single-stream or county data were missing, and whether the time between surveys was one or two years. *significant at 10%; **significant at 5%; ***significant at 1%.

Table 6
Ordered Logit Regressions for Recycling Any Material or All Four Materials.

Changes in	Recycle Any Material (−1 / 0 / +1)	Recycle All Four Materials (−1 / 0 / +1)
County total materials recycled	0.02628 ***	0.02730 ***
	0.00098	0.00097
Single-stream	0.01075 ***	0.01556 ***
	0.00215	0.00244
Deposit law in state	0.02652 ***	0.01956 **
	0.00606	0.00803
Effective recycling laws	0.03098 ***	0.01437
	0.01044	0.01153
Paper price per pound	−0.01754	−0.08728
	0.12242	0.13158
Cans price per pound	0.02910	0.07935 ***
	0.02419	0.03070
Glass price per pound	0.35978 *	0.40543
	0.21750	0.27274
Plastic price per pound	0.02787	−0.03678
	0.03685	0.05160
Income increase larger than 20%	−0.00263	−0.00195
	0.00162	0.00166
Income decrease larger than 20%	−0.00894 ***	−0.00856 ***
	0.00233	0.00231
Apartment	−0.00564 **	−0.00773 ***
	0.00245	0.00234
Unemployed	0.00530 **	0.00122
	0.00218	0.00222
Retired	0.00409 **	0.00277
	0.00205	0.00249
Homeowner	−0.00107	0.00234
	0.00237	0.00240
Married, yes	−0.00443	−0.00629 *
	0.00348	0.00351
Household size	0.00121	−0.00012
	0.00111	0.00119
Infant in home (age 1 or less)	−0.00841 ***	0.00129
	0.00253	0.00219
Years of education	−0.00203	−0.00005
	0.00211	0.00211
Democrat	0.00138	0.00097
	0.00197	0.00200
Legislature recently (2 yr) Democrat	0.00087	−0.00013
	0.00078	0.00096
Legislature recently (2 yr) Republican	−0.00471 ***	−0.00200 **
	0.00080	0.00081

Notes: N = 232,309. Marginal effects reported. Robust standard errors in parenthesis, clustered by 82,098 households. Ordered logit regressions also included year-fixed effects and indicator variables for whether single-stream or county data were missing, and whether the time between surveys was one or two years. *significant at 10%; **significant at 5%; ***significant at 1%.

household comes to recycle all four materials, 0 if the household didn't change in whether it recycled all four materials, and − 1 if the household ceased recycling all four materials. As before, all explanatory variables are in terms of changes in these variables.

It is interesting to compare the results for the threshold recycling decision relative to the fully diligent recycling decision. For many of the variables, the magnitudes and statistical significance of the coefficients are similar. Both the county recycling variable and the single-stream variable are strongly significant with similar coefficients in both regressions. Deposit laws are also statistically significant, but with a somewhat smaller coefficient in the all-four materials regression. Reasonably, deposit laws are more successful in leading households to become recyclers than incentivizing households to become complete recyclers. Recycling laws have a positive and statistically significant relationship to becoming a recycler but have a smaller coefficient that is not statistically significant for recycling all four materials. Those results suggest that both deposits and recycling laws have greater impact in areas with low levels of current recycling.

The price change variables are less consequential in the analysis of two extremes of recycling behavior than in the previous regressions regarding more continuous measures of recycling. As in the core regression estimates, the positive coefficients for higher prices for cans and in the all-four materials regression are consistent with the hypothesis that higher prices for cans boost recycling.

Shifting to a political environment with Republican legislative control has a statistically significant negative coefficient for whether the household recycles for either of the two measures in Table 6. However, there are no other statistically significant coefficients for the other political variables.

For the gradations in recycling analyzed previously, income changes larger than 20% in either direction had significant negative coefficients. Here however, only the decrease in the income coefficient is statistically significant in the estimates for the two measures of extremes in recycling shown in Table 6. Income decreases are associated with reduced recycling whether one becomes a first-time or a diligent recycler.

The only other statistically significant variable in both equations is moving into an apartment, which is associated with a drop in the probability of whether the household recycles at both extremes. Some of the other variables, such as becoming unemployed, becoming retired, or having an infant in the household are each statistically significant in only one of the regressions in Table 6.

Examination of the extremes in recycling behavior at the bottom and top levels of recycling replicate the main policy-related pivotal relationships from the earlier results. To the extent that the other variables are statistically significant, the signs of the coefficients are the same as in the core regression and other tables. However, more variables play a significant role in explaining the gradations of recycling behavior than in explaining behavior at the extremes.

4.3. Regressions by amount of time between surveys

The results in Table 3 control for the *time since previous survey, in years*, which has a significant coefficient of 0.03 materials increase per year, suggesting a significant gradual increase in recycling with one year of additional time. To better understand this relationship, this section considers separate subsamples for the time between surveys. The first column of Table 7 uses a subsample of data for which survey pairs span only one year, and the second column uses data for which survey pairs span two years.

The magnitudes of coefficients align with those in column one of Table 3. However, there are some notable differences. The coefficients for both deposit laws and recycling laws have larger estimates for the surveys conducted two years apart, suggesting that such laws have a persistent and growing associations over time for recycling. Changes in the state legislature to Democratic control have a significant negative coefficient for changes in recycling in the two-year subsample. Considering this result along with the negative coefficient for newly Republican control in Table 3 and the one-year subsample in Table 7, it is possible that volatility in state government may generally have a negative influence on recycling.

Large annual changes in household income had negative coefficients in Table 3. Here, the coefficient is not statistically significant for the two-year span between surveys for large income increases, while the coefficient is larger over time for large income decreases. This difference suggests that while any household shock can disrupt recycling, negative shocks may have more persistent relationships. The weakening negative impact of a positive income change is consistent with a shock of an increase disrupting recycling in the short term but permitting positive cross-sectional associations between income and recycling in the long term (Miafodzyeva and Brandt, 2012; Coffee and Joseph, 2013).

Table 7
Regressions for Change in Number of Materials Recycled (−4 to +4), by Amount of Time Between Surveys.

Changes in	Coefficient, One-year between Surveys	Coefficient, Two-years between Surveys
County total materials recycled	0.2505***	0.2447***
	(0.0075)	(0.0132)
Single-stream	0.1200***	0.0652**
	(0.0155)	(0.0302)
Deposit law in state	0.1805***	0.2177*
	(0.0497)	(0.1128)
Effective recycling laws	0.1291	0.2826*
	(0.0825)	(0.1531)
Paper price per pound	−0.1797	−0.5494
	(0.8084)	(1.7003)
Cans price per pound	0.3358*	0.9475**
	(0.1766)	(0.4156)
Glass price per pound	4.3485**	0.7838
	(1.8040)	(2.5103)
Plastic price per pound	0.2047	0.2631
	(0.3560)	(0.4028)
Income increase larger than 20%	−0.0388***	0.0024
	(0.0119)	(0.0165)
Income decrease larger than 20%	−0.0705***	−0.0916***
	(0.0143)	(0.0294)
Apartment	−0.0628***	−0.0579**
	(0.0174)	(0.0244)
Unemployed	0.0378***	0.0345
	(0.0146)	(0.0300)
Retired	0.0291*	0.0114
	(0.0162)	(0.0271)
Homeowner	0.0026	−0.0039
	(0.0172)	(0.0249)
Married, yes	−0.0540**	−0.0307
	(0.0268)	(0.0302)
Household size	0.0103	−0.0052
	(0.0075)	(0.0194)
Infant in home (age 1 or less)	−0.0368**	−0.0746
	(0.0144)	(0.0677)
Years of education	−0.0270*	0.0035
	(0.0156)	(0.0214)
Democrat	−0.0031	−0.0065
	(0.0132)	(0.0278)
Legislature recently (2 yr) Democrat	0.0113*	−0.0488***
	(0.0064)	(0.0149)
Legislature recently (2 yr) Republican	−0.0202***	−0.0199
	(0.0058)	(0.0140)
Observations	185,130	47,179

Notes: Robust standard errors in parenthesis, clustered by household. OLS regressions also included year-fixed effects and indicator variables for whether single-stream or county data were missing and a constant term. *significant at 10%; **significant at 5%; ***significant at 1%.

5. Conclusion

The consistent theme of this analysis is that recycling is not an immutable behavior but is responsive to short-term influences that alter household recycling. The recycling environment is clearly consequential in affecting an assessment of the households' benefits and costs from recycling, as are influences likely to affect this environment such as changes in the prices of recycled materials and political control of the state legislature. Similarly, the benefits and costs to household influence recycling rates. In particular, disruptive household changes that are not readily subject to policy influence can generate an immediate negative shock on recycling rates. Changes in the policy instruments intended to influence recycling by changing the recycling environment can drive changes in recycling behavior.

The insights obtained by analyzing a large sample of changes in recycling behavior provide a nuanced perspective on the relative stability of recycling behavior. While there is some validity to the belief that there is substantial continuity of recycling behavior over time and that the recycling environment does matter, other changes are influential as well. The household's level of recycling is not a flat line. What is especially noteworthy is that the relationship between recycling and the explanatory variables is robust across recycling measures. The results replicate across counts of materials recycled, increases or decreases in materials recycled, and a qualitative ordering of the intensity of recycling.

While the relationships are statistically reliable, many of the short-term estimates in the changes analysis are small, in part because recycling rates are already quite high. In our national sample, 85% of the households recycled at least one material in the previous year, with the probability that the household recycles the materials ranging from 0.62 for glass to 0.76 for cans. Also, most analysis variables are relatively stable from year to year. Despite these obstacles, the large sample size allows us to measure how changes in households, their region, and government policies are associated with changes in recycling.

A prominent change variable is the county recycling rate, as there is a

0.25 increase in the number of materials recycled in counties experiencing a recycling rate increase of 1 material that is recycled. This positive but less than proportional relationship reflects the visible impact of being able to witness more neighborhood recycling activity as well as how amenities that the county may have introduced relate to county recycling.

Prices of recycled materials can affect the financial benefits that municipalities reap from recycling. The strongest relationship between changes in recycling and materials price changes is that for cans, for which a doubling of the price of cans would be associated with a recycling increase of 0.33 materials, a 12% increase. That relationship could emerge from greater collection intensity in areas that have deposit laws or increased encouragement to recycle from municipalities that could benefit.

The study includes identifiers for three governmental factors associated with changes in recycling beyond the change in each county. Governmental variables are led by the shift to deposit laws (reflecting a 7% increase in recycling), followed by a move to a state with effective recycling laws (6%), and the introduction of single single-stream recycling (4%).

There are a number of changes that have different signs compared with cross-sectional estimates. The negative relationship of changes in recycling behavior to a 20% change in household income in either direction at first seems paradoxical. Cross-sectional analyses have generally shown that households with higher incomes and jobs recycle more materials. However, the decline in recycling from shifts in income in either direction may reflect short-term shocks and the greater difficulty that these shocks pose for households' recycling behavior. Similarly, while being married is generally positively associated with recycling, becoming married is negative related to changes in recycling, as is having an infant in the home.

The important point is that the empirical examination of changes has different meaning and usefulness than cross-sectional analyses. Change analyses focuses on variables that change often and measures the short-term relationships between changes in the explanatory variables and changes in recycling rates, while the more common cross-sectional analysis reflects long-term balance between competing factors.

Declaration of Competing Interest

The authors have no competing interests and received no external financial support for this article.

Data availability

The authors do not have permission to share data.

References

Aadland, David, Caplan, Arthur J., 2006. Curbside recycling: waste resource of waste of resources? J. Policy Anal. Manag. 25 (4), 855–874.

Abbott, Andrew, Nandeibam, Shasikanta, O'Shea, Lucy, 2011. Explaining the variation in household recycling rates across the UK. Ecol. Econ. 70, 2214–2223.

Abbott, Andrew, Nandeibam, Shasikanta, O'Shea, Lucy, 2013. Recycling: social norms and warm-glow revisited. Ecol. Econ. 90, 10–18.

Abbott, Andrew, Nandeibam, Shasikanta, O'Shea, Lucy, 2017. The displacement effect of convenience: the case of recycling. Ecol. Econ. 136, 159–168.

Ashenmiller, Bevin, 2009. Cash recycling, waste disposal costs, and the incomes of the working poor: evidence from California. Land Econ. 85 (3), 539–551.

Ashenmiller, Bevin, 2010. Externalities from recycling Laws: evidence from crime rates. Am. Law Econ. Rev. 12, 245–261.

Ashenmiller, Bevin, 2011. The effect of bottle laws on income: new empirical results. Am. Econ. Rev. 101 (3), 60–64.

Bel, Germa, Gradus, Raymond, 2016. Effects of unit-based pricing on the waste collection demand: a meta-regression analysis. Resour. Energy Econ. 44, 169–182.

Bell, Jason, Huber, Joel, Kip Viscusi, W., 2017. Fostering recycling participation in Wisconsin households through single-stream programs. Land Econ. 93 (3), 481–502.

Best, Henning, Kneip, Thorsten, 2019. Assessing the causal effect of curbside collection on recycling behavior in a non-randomized experiment with self-reported outcome. Environ. Resour. Econ. 72, 1203–1223.

Bohara, Alok K., Caplan, Arthur J., Grijalva, Therese, 2007. The effect of experience and quantity-based pricing on the valuation of a curbside recycling program. Ecol. Econ. 645, 433–443.

Coffee, Daniel J., Joseph, Patricia Hallam, 2013. A polarized environment: the effect of partisanship and ideological values on individual recycling and conservation behavior. Am. Behav. Sci. 57 (1), 116–139.

Czajkowski, Mikolaj, Zagorska, Katarzyna, Hanley, Nick, 2019. Social norm nudging and preferences for household recycling. Resour. Energy Econ. 58, 1–17.

Fullerton, Don, Kinnaman, Thomas C., 1996. Household responses to pricing garbage by the bag. Am. Econ. Rev. 86, 971–983.

Gilli, Marianna, Nicolli, Francesco, Farinelli, Paola, 2018. Behavioural attitudes towards waste prevention and recycling. Ecol. Econ. 154, 294–305.

Halvorsen, Bente, 2008. Effects of norms and opportunity cost of time on household recycling. Land Econ. 84 (3), 501–516.

Hong, Seonghoon, Adams, Richard M., 1999. Household responses to price incentives for recycling: some further evidence. Land Econ. 75, 505–514.

Huber, Joel, Kip Viscusi, W., Bell, Jason, 2018. Dynamic relationships between social norms and pro-environmental behavior: evidence from household recycling. Behav. Public Policy 1–25. February.

Jenkins, Robin R., Martinez, Salvador, Palmer, Karen, Podolsky, Michael J., 2003. The determinants of household recycling: a material specific analysis of recycling program features and unit pricing. J. Environ. Econ. Manag. 45 (2), 294–318.

Kinnaman, Thomas C., 2006. Policy watch: examining the justification for residential recycling. J. Econ. Perspect. 20 (4), 219–232.

Kinnaman, Thomas C., 2014. Determining the socially optimal recycling rate. Resour. Conserv. Recycl. 5–10.

Kinnaman, Thomas C., Fullerton, Don, 2000. Garbage and recycling with endogenous local policy. J. Urban Econ. 48, 419–442.

Miafodzyeva, Sviatlana, Brandt, Nils, 2012. Recycling behavior among householders: synthesizing determinants via a meta-analysis. Waste Biomass Valorization 4 (2), 221–235.

Oskamp, Stuart, Linnette Zelezny, P., Schultz, Wesley, Hurin, Sharrilyn, Burkhardt, Rachael, 1996. Commingled versus separated curbside recycling – does sorting matter? Environ. Behav. 28 (1), 73–91.

Reschovsky, James D., Stone, Sarah E., 1994. Market incentives to encourage household waste recycling: paying for what your throw away. J. Policy Anal. Manag. 13 (1), 120–139.

Van Houtven, George L., Morris, Glenn E., 1999. Household behavior under alternative pay-as-you-throw systems for solid waste disposal. Land Econ. 75, 515–537.

Viscusi, W. Kip, Huber, Joel, Bell, Jason, 2011. Promoting recycling: private values, social norms, and economic incentives. Am. Econ. Rev. 101 (3), 65–70.

Viscusi, W. Kip, Huber, Joel, Bell, Jason, 2012. Alternative policies to increase recycling of plastic water bottles in the United States. Rev. Environ. Econ. Policy 6 (2), 190–211.

Viscusi, W. Kip, Huber, Joel, Bell, Jason, Cecot, Caroline, 2013. Discontinuous behavioral responses to recycling laws and plastic water bottle deposits. Am. Law Econ. Rev. 15 (1), 110–155.

Viscusi, W. Kip, Huber, Joel, Bell, Jason, 2023. Quasi-Experimental Evidence on the Impact of State Deposit Laws and Recycling Laws: Household Recycling Following Interstate Moves. http://ssrn.com/abstract=3536613.