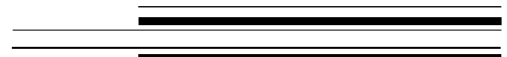**Revised July 2, 2018**

Convenient Beverage Recycling in California

A Report to the California State Legislature

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This report is pursuant to the agreement DRR15053 between CalRecycle and the Regents University of California with Peter Berck and Sofia Villas-Boas as principal investigators.

Introduction and Summary

This report is divided into three principal sections. The first section reports on how the public defines convenience in recycling opportunities and who recycles. This section of the report makes use of two surveys. 1. A representative survey of Californians that was designed and tested at Berkeley and implemented by NORC at the University of Chicago. 2. A survey of recycling center users conducted at recycling centers across the State, which was devised, tested, and administered by the Berkeley team. The key findings of this section are:

1. Nearly all Californians know of the recycling program and where they can recycle.
2. Only 8% of Californians say they throw containers in the trash. The remainder use either curbside or return containers at a recycling center for the CRV.
3. Ninety two percent of recycling center users arrive at centers by car. Users report that the travel and wait times are acceptable and that they would be willing to invest about five additional minutes travelling to centers.
4. Users define the primary elements of convenience as: time spent travelling to recycling centers, centers' hours of operation, and time spent in line at recycling centers.
5. If the CRV were increased to 7 cents, 34% of those who use curbside and 11% of those who put their containers in the trash say they would recycle for the CRV. Since only 8% place containers in the trash, the increase in the recycling rate would be less than 1%.
6. Sixty-nine percent of the respondents who recycle for CRV come from the bottom half of the income distribution. The 30% of Californians with family income over $100,000 account for 11% of those who say they recycle for CRV. Additionally, curbside users are more likely to be urban and not identify as Hispanic or Black.
7. The users do not report convenient recycling opportunities have either improved or deteriorated over time.
8. No modest increase in opportunities to recycle will meaningfully change the convenience of recycling in the state. The average distance from the center of

each zip code in the state to the nearest recycling center was 2.76 miles in 2006 and is 2.73 miles in 2017. The state had almost 200 more recycling opportunities in 2006 than 2017.

9. Diverters have low incomes (< 10,000 median) and concentrate in the 35-54-year-old age range. Twenty-six percent of all returns to recycling centers comes from diversion (trash or recycling bins.) Our best estimate is that about 4% of diversion comes from recycling bins.

10. Non-diverting recyclers make about 1 trip per month to a recycling center. Those returning material that was 75% or more diverted make three or more trips per week to a center.

11. Open hours for supermarket located centers do not match peak shopping hours. This makes these centers inconvenient.

The second section of this report presents econometric models and analysis of recycling center and recycling user behavior. Using data provided by CalRecycle and the two survey data sources described above, we model the response of recycling centers to changes in the handling fee structure and revenue-per-container, as well as the responses of users to monetary incentives and the convenience of center location and hours. The models also draw from publicly available county data including weather and income. There are four econometric models, one to estimate the response of recycling behavior to the convenience of and to the monetary incentive to recycle. The second captures the effect of the 2008 change in fee structure on handling fee centers. The third model relates the number of centers operating to the average revenue per containers. The fourth model simulates consumers' disposal choices under a 33%, 67%, and 100% change in the number of handling fee centers, and a 100% increase in the CRV. The results are as follows:

1. Center revenue depends on scrap sales, handling fees, and processing payments. The processing payments buffer the centers from changes in scrap value for all materials, but aluminum. The current methodology sets handling fees based on container weighted average operating costs across all recycled materials and all centers. As larger centers have a lower per container operating cost, this sets handling fees below the break-even point for some small centers.

2. As of the end of 2016, the per container revenue was below the container weighted average cost for all three sizes of handling center. Lower scrap values for materials other than aluminum result in higher payments by the Fund. Lower

aluminum scrap values result in lower revenue for centers. Aluminum scrap value has been falling, resulting in depressed revenue for centers.

3. Convenient recycling depends upon the number of centers and their size. A one penny increase in revenue to recycling centers would lead to about 120 more centers, a large fraction of which would be smaller sized centers.

4. A closure of 1/3, 2/3, or all of the handling centers across California would not have a major impact on the welfare of California residents, except perhaps for rural consumers that may live a significant distance away from any other recycling centers.

5. An 100% increase in the CRV would reduce the number of containers entering the curbside and trash streams, which would lower the revenue obtained by Cal Recycle for unredeemed containers but would also lower the environmental costs, since more containers would be recycled at recycling centers. Wealthier consumers who were on the fence about using recycling centers are the most likely to change their disposal methods due to a CRV increase.

6. Both the Amerispeak survey and results from the econometric models suggest a modest response by consumers to a change in the CRV and a minimal response to an increase of 100 centers.

The third section contains alternatives and recommendations. These are guided by the twin pillars of providing consumer convenience and attaining an 80% return rate.

1. We recommend that the definition of convenient recycling be: recycling at centers that are nearby, open convenient hours, and have short lines.

2. We do not recommend taking any special action to save the smaller handling fee centers.

3. We do recommend considering easing the convenience zone requirement. In granting exemptions, CalRecycle should be mindful of the local, not statewide, patterns of car use. At the current density of recycling centers, losing additional centers has very little effect on overall collection.

4. We do not recommend increasing the payment to handling centers even though increasing the handling fee will lead to increasing the number of centers, because it will lead to more high cost centers.

5. Lowering the cap on material returnable in a day will not make a difference to most diverters.

6. Should scrap values continue to trend lower or if the Fund should need to correct a structural deficit, a higher CRV for PET, Glass, and HDPE will bring in more revenue to the Fund and only modestly increase recycling.

7. If increased convenience is required, the requirement for open hours for handling fee centers should be changed to better match shopping hours.

Background

To encourage recycling and reduce litter, California implemented AB2020 (the Act) in 1987. The aims of the Act were to increase the recycling rate to 80% of all recyclable containers and to provide for consumer convenience. The major players affected by the Act are consumers and retailers of recyclable materials, recycling centers, processors, beverage manufacturers, curbside collectors, and the State Beverage Container Recycling Fund (the Fund).

From a consumer's point of view, the program requires consumers to pay a redemption value for each eligible beverage container at the time of purchase. When the container is empty, the consumer may then take it to a state certified recycling center and receive a refund. The refund is the California Redemption Value (CRV) payment. A unique aspect of the Act is that containers may be redeemed by weight. Redemption by weight is much less time consuming than counting containers.[1]

From a retailer's point of view, the program requires the retailer to charge a CRV to the consumer. Notably, it does not require the retailer to handle container returns at all. In order to provide for convenient recycling without having retailers handle bottles, the Act established convenience zones — a half-mile radius around any supermarket with $2 million or more in annual sales — and required that there be a recycling center co-located with a supermarket within each zone. When this requirement is not met, the retailer must either take back the containers and pay the CRV to the consumer, pay a $100 per day fine, or obtain an exemption. The fundamental tenet of the Act was that retailers traded the obligation to take back containers against an obligation to provide for convenient recycling by another entity. Centers that are the first to be located in a convenience zone receive a special payment, called the handling fee. Hence, they are called handing fee centers.

A certified recycling center receives eligible containers and pays consumers the CRV. It may also pay the consumer a scrap value beyond the CRV at its discretion. The center sells its containers to a processor and receives a payment that includes a processing

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[1] If recycling more than 50 containers of any one material type, the decision to pay by count or weight is determined by the recycling center operator. There is a limit of 100 lbs of each type of material per day. (CalRecycle)

payment, an administrative fee, the CRV, and possibly a payment for the value of the scrap. In addition, handling fee centers also receive the handling fee.

Processors pay the recycling centers the CRV and other payments. In turn, they collect the CRV, an administrative fee, and the processing payment and handling fees from the Fund. They sell the material to end users of the scrap.

The Fund accepts payment of the CRV, less an administrative fee, from beverage manufacturers. It also collects a processing fee from the manufacturers. It pays out the handling fee, processing payment, and administrative fees as well as makes a variety of payments including curbside supplemental payments.

At present, the CRV is 5 cents for a container less than 24 oz and 10 cents for larger containers.

The reimbursement to handling fee centers has changed considerably over the life of the Act. AB2020 established Convenience Incentive Payments (CIP) paid to recycling centers located in convenience zones. In 1992, AB87 replaced CIP with a 1.7 cent per container handling fee and centers could receive a maximum of $2,300 per month per center. Additionally, the maximum payment of handling fees was set at $18.5 million for all centers per year. The amount of maximum handling fees fluctuated until 2008 when new legislation was implemented to recalculate handling fees through cost surveys of these centers.

In 2008, CalRecycle began using cost surveys of recycling centers to determine handling fee payments. The survey calculated the difference between the weighted average cost of recycling at handling fees centers and the weighted average cost of recycling at processing fee centers. The handling fee was this difference. In addition, the new legislation removed the $2,300 per month cap a center could receive. The reform resulted in a lower handling payment.

After this new legislation, many small centers ceased operation because the costs to operate were higher than their revenue. When small centers, the centers that have the highest costs of operation, close, the average cost of operation decreases because the small centers' higher cost data points are no longer pulling up the computed average cost. Thus, the handling fee to centers decreases, which in turn decreases the profitability of the remaining small centers in operation. With the decrease in the number of handling fee centers, the composition of centers has shifted from 52% processing fee centers and 48%

handling fee centers in 2004 to 61% processing fee centers and 39% handling fee centers in 2012. The total number of recycling centers has also changed over that time period and is currently in decline.

The interaction between the handling fees, the number of centers, and consumer convenience is one of the topics covered in this report. More generally, we will delineate what makes recycling convenient in the eyes of consumers.

Recycling Center Convenience

Surveys

We conducted two surveys of Californians about beverage container recycling. The AmeriSpeak survey is representative of all Californians, while the second survey was an intercept survey conducted at recycling centers and is representative of trips made by users of those centers. Frequent recycling center users, people who visit every three days or fewer, have a higher chance of participating in the intercept survey than the average Californian since the intercept survey is representative of trips made to recycling centers and the source of the containers returned to centers.

The Berkeley team engaged NORC at the University of Chicago to administer our recycling survey to a representative sample of Californians. AmeriSpeak is a representative panel with over 2800 participants from California. These panel members receive rewards for answering surveys such as ours. The key issues in administering surveys are representativeness of the panel itself and obtaining a representative set of responses from that panel.

NORC describes its coverage this way:

"The fundamental advantage of the AmeriSpeak Panel is that it is probability based, producing response rates for clients that are significantly higher than any we have seen from publicly-available household panels. The foundation of our panel is the NORC National Frame, an area probability sample frame that provides sample coverage of 97% of U.S. households for the AmeriSpeak Panel, the General Social Survey, the FTC Survey of Consumer Finances, and other studies. The National Frame contains almost 3 million households, including over 80,000 rural households added through the in-person listing of households that were not recorded on the United States Postal Service (USPS) Delivery Sequence File. This ensures comprehensive coverage and representation of the U.S. population, as well as minimal design effect."

NORC obtains representative responses by taking two major steps. First, the panel is free to respond by either telephone or internet. This is important because low income groups and the elderly, among others, do not have access to the internet or are not comfortable using the internet. Second, the survey was available in both English and Spanish because an appreciable portion of Californians are primary Spanish speakers. NORC also has protocols for encouraging responses, if needed, and weighting the responses to make the answer representative.

The University of California, Berkeley NORC survey utilized 1000 households in California, chosen to be a representative sample of the state. A survey of 1000 California households has an error rate of 3% with 90% confidence level.

Our team conducted an intercept survey at recycling centers randomly selected throughout California. Surveyors asked recyclers 25 questions regarding their recycling habits and requested a copy of their receipt. The purpose of this survey was to learn about people who recycle frequently, such as people who divert containers from the trash or from curbside collection. Sampling people who come to centers gives many more observations on these people than does a general survey of the California population. The survey included 88 recycling centers and 628 participants. The survey was designed to have an error rate of 10% with 90% confidence under an assumption that the people surveyed in each recycling center would not be completely independent draws. If the people are viewed as independent draws, the error rate would be closer to 4%.

Definition of Convenience
Data from both surveys were used to determine an appropriate definition of convenience.

Respondents from the AmeriSpeak survey listed 'nearby' (73%) and 'extended hours of operation' (48%) as the top two reasons for choosing recycling centers. In addition, although 41% of AmeriSpeak respondents who visit recycling centers use centers in convenience zones, only 17% of respondents state that having a recycling center in their store parking lot was important to them, suggesting that handling fee centers may not be essential for households.

As seen in Figure 1 using intercept survey data, 70% of respondents listed 'close to home or work' as their top reason for selecting a recycling center, and 'open at good times' (21%) as well as 'short lines' (18%) were also key factors. 75% of recyclers are aware of other centers available to them and selected a recycling center with an average wait time of ten minutes.
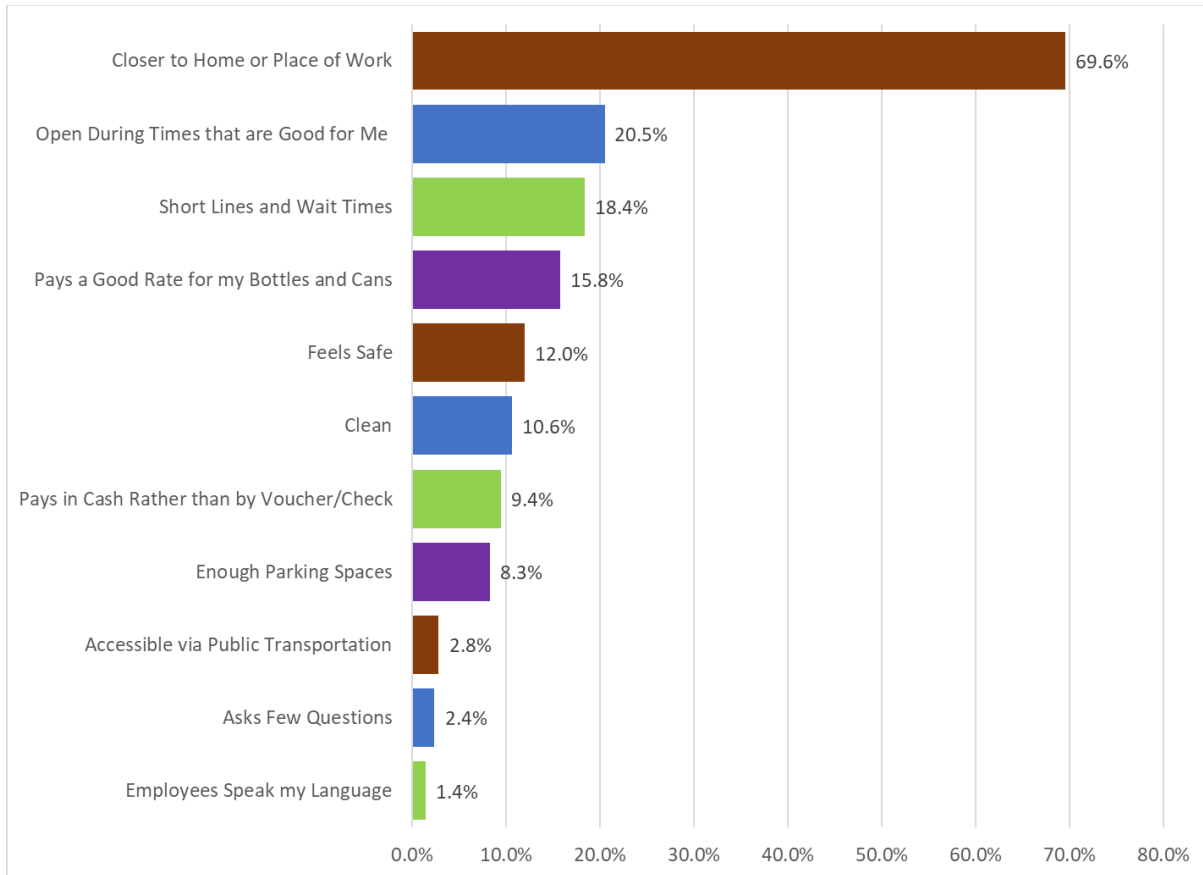
Figure 1: Top Reasons for Choosing a Recycling Center

In the intercept survey, people were asked to choose from eleven options for why they redeemed bottles at the recycling center. The top three reasons were 'close to home' (70%), 'open at good times' (21%), and 'short lines and wait times' (18%).

Source: Intercept Survey conducted by the University of California, Berkeley research team.

Based on these observations, we define convenient recycling opportunities as a recycling centers that are close to home or work, open at good times, and have short wait lines.

Transportation to Centers

The AmeriSpeak survey found that driving to a center is the most common mode of transport, with 93% of AmeriSpeak respondents who recycled at centers stated driving to recycling centers to redeem containers. In the intercept survey 85% of respondents drove

to the recycling center. As seen in Figure 2, the next most popular mode of transportation was walking, with 9% of respondents.
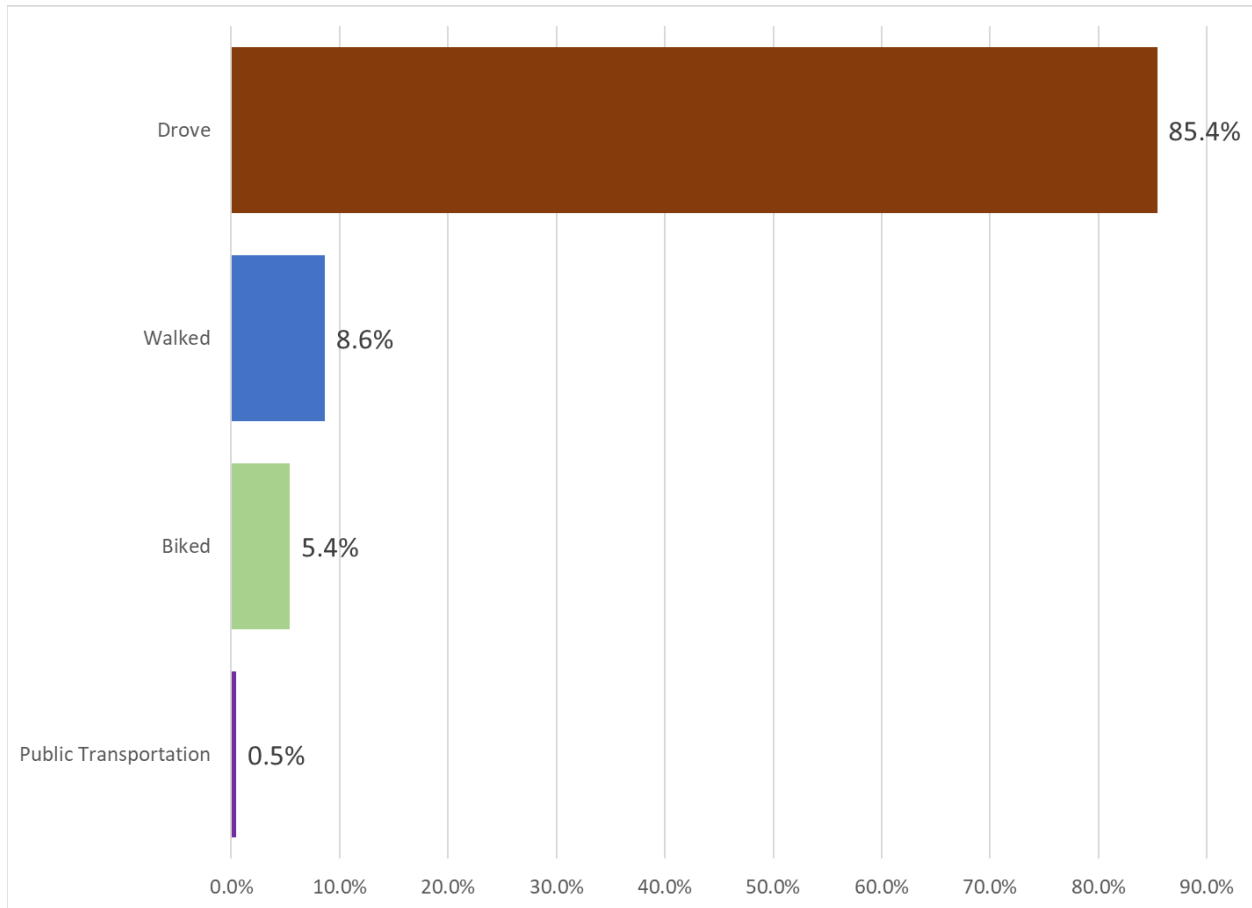

Figure 2: Transportation to Recycling Center of Frequent Recyclers

From the intercept survey, 85% of trips to the recycling center were done by driving. This total is out of 625 people who responded to this question. Each person took one trip.

Source: Intercept Survey conducted by the University of California, Berkeley research team.

Willingness to Travel
To understand how people internalize their time, we calculate their CRV payment per minute of traveling to a recycling center. The average person makes $1.39 per minute

redeeming bottles using the time spent traveling to the center and waiting in line[2]. The median time to drive to a center is 10 minutes and 5 minutes is the median time waiting in line.

This payment is important when understanding how people state their willingness to travel and wait at a center. In Figure 3 and Figure 4 we look at people's acceptable travel and wait time versus their current travel and wait time. Figure 3 plots acceptable travel time against typical travel time with a 45-degree line showing people who are traveling their maximum acceptable distance. Figure 4 plots acceptable wait time against typical wait time with a 45-degree line showing people are waiting their maximum acceptable length of time. Plot points that fall above the 45-degree line correspond to people who find their current travel or wait times to be acceptable, while points that fall below the 45-degree line correspond to people who are currently traveling or waiting longer than what they believe is acceptable.

In Figure 3, frequent recyclers typically travel what they view as an acceptable amount of time and indicate that they would be willing to travel further. The average time people typically travel is 10 minutes while the median time people travel is 5 minutes. People also responded with a mean willingness to travel of 15 minutes and median of 10 minutes to travel to a recycling center.

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[2] The $1.39 figure results from calculating CRV payment per minute of time for each respondent and then averaging these values across all respondents.
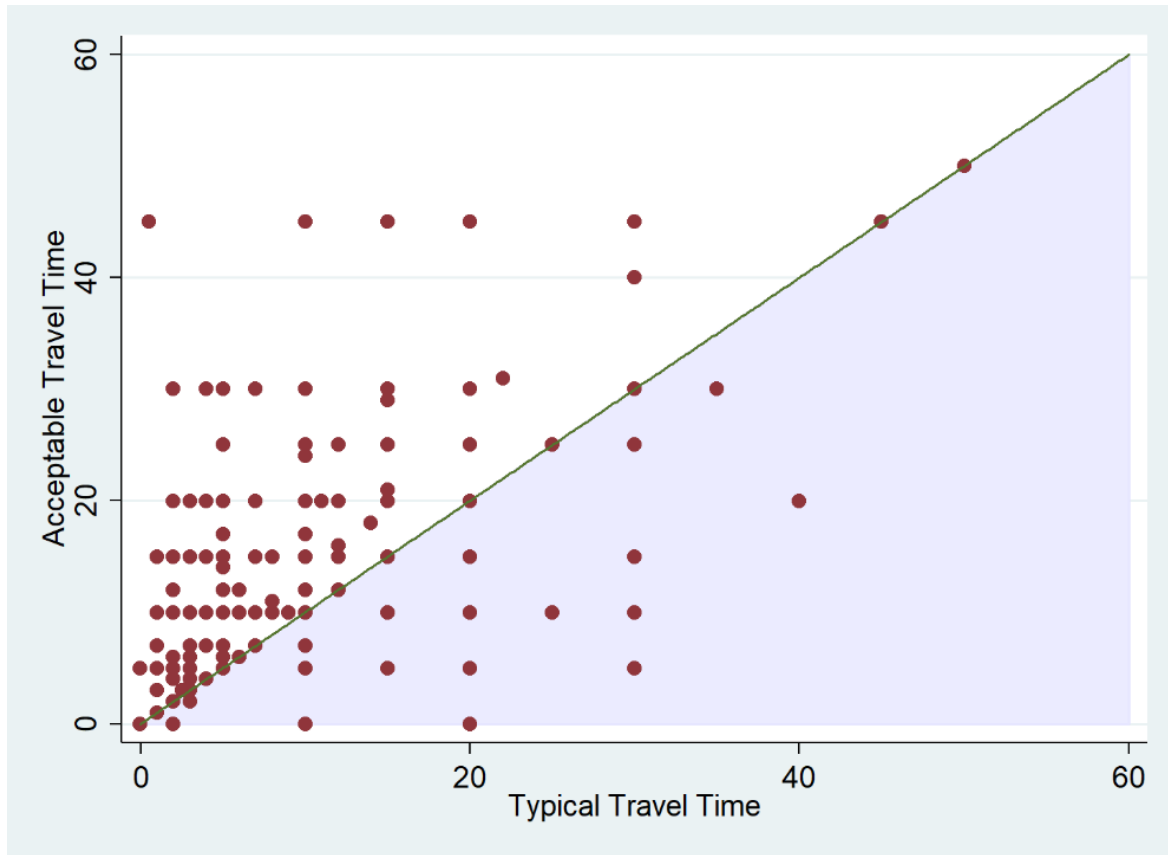
Figure 3: Travel Time Plotted Against Acceptable Travel Time

We can see above that most people are traveling less than what they consider an acceptable distance. We can conclude that there are currently convenient recycling opportunities since people are recycling at centers closer than their furthest willingness to travel. In the intercept survey, the average distance people traveled 10 minutes to a recycling opportunity. The average stated acceptable distance people are willing to travel to a recycling center is 15 minutes. Source: Intercept Survey conducted by the University of California, Berkeley research team.

People's response to waiting to recycle follows a similar pattern. As seen below in Figure 4, people are willing to wait longer at recycling centers than their current typical wait times. On average, people wait 10 minutes, with a median of 5 minutes at a recycling. They are willing to wait an average of 16 minutes and a median of 10 minutes to recycle.
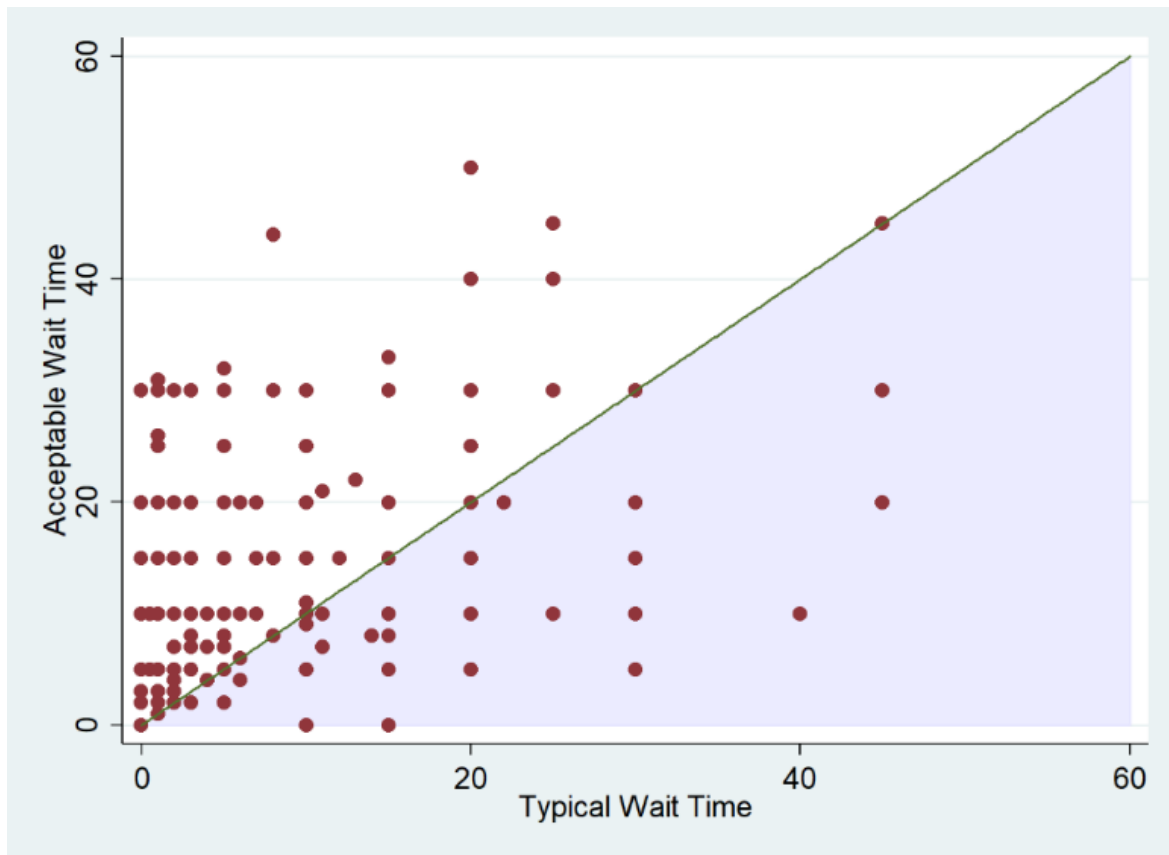
Figure 4: Wait Time Plotted Against Acceptable Wait Time

The average time people wait at a recycling center is slightly less than 10 minutes while the average time people are willing to wait at a recycling center is 16 minutes. Source: Intercept Survey conducted by the University of California, Berkeley research team.

The distance people have had to travel on average has not drastically changed over the years. As seen in Figure 5 and Figure 6 showing the number of recycling centers in California for 2006 and 2017 respectively, the number of recycling centers has remained relatively constant and no visual difference can be seen without a deeper numerical analysis.

Figure 5: 2006 Recycling Centers

Figure 6: 2017 Recycling Centers

Beverage Containers in Trash

The AmeriSpeak survey had 1000 respondents with only 8% saying that they threw CRV containers into the trash in the past week rather than recycle them. In terms of containers, there were 35,120 total containers of which 3523 (10%) were put in the trash.[3]

CRV Values on Recycling

Survey respondents were asked if a change in CRV would induce them to bring containers back to recycling centers. The number of people who said they would redeem their containers at a recycling center increased with the CRV. Of the people who said that they were currently throwing their beverage containers in the trash, it took an increase in the CRV to 15 cents before more than half said they would start taking containers to a recycling center. For those using trash for disposal, an increase to 7 cents lead to 11% saying they would redeem and an increase to 10 cents lead to 35% saying they would redeem. Of people who said that they were currently using curbside bins to recycle their beverage containers, an increase in the CRV to 15 cents was necessary before more than half would start taking containers to a recycling center, as well. At a CRV of 7 cents, 34% said they would redeem and at a CRV of 10 cents 41% said they would redeem. For

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[3] Population weighted

instance, the 2016 PET recycled share was 76 percent. The recycled share would go from 76% to 78% with a 7 cent CRV.

The survey respondents who use curbside were much more responsive to a potential increase in CRV than those who threw out their containers. The same increase of CRV to 7 cents would lead to a 34% reallocation of recycling from curbside to recycling centers.

Change in Convenience

AmeriSpeak survey respondents were asked if they found recycling to be harder or easier than in the previous year. This has mixed results — about 12% said it was easier (with increased access to curbside services), 9% said it was harder (with the closure of recycling centers), 66% said they had experienced no change, and the rest were not sure.

On average, people live 2.73 miles away from their closest recycling center. It should also be noted that almost all people in California also have access to a curbside recycling program in efforts by cities to decrease material to landfills. The respondent group that did not take their recyclable materials to a recycling center reported they felt it was not worth the money, although the time and effort required to sort the material and take it to the center were regularly cited choices as well. For people who responded that they lived too far away from their nearest center, the average distance to the nearest center was 3.39 miles.

In general, information about recycling and its benefits is largely known, and likely not a major barrier to recycling opportunities. Out of the 78 individuals who put their containers in the trash, only 12 of them did not know about CRV redemption or where to take recyclable materials.

Recycling Opportunities

Definition of Recycling Opportunities

In our data of recycling centers, if a center changed ownership or relocated less than 120 yards, we treated that center as a single recycling opportunity.[4]

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[4] For example, if a recycling center changed ownership in a month then the data showed two observations even though only one center was operating. The same is true if a recycling center relocated across a parking lot.

The recycling opportunities refer to either a handling fee recycling center or a processing fee recycling center. We found that centers located within the same area generally maintained the same center type, so our specification is reliable. However, it is important to note that our specification of recycling opportunity may be the reason for differences in the number of centers when compared to other reports.

Recycling Use

Recycling centers are most heavily used by people who make less than $50,000 per year. The higher income groups are more likely to use curbside as their preferred disposal method. The median household income in California is $63,783[5]. Sixty nine percent of the for CRV recyclers come from the lower half of the income distribution, while the 30% of the households that have an income over $100,000 account for only 11% of the CRV redemption. Education was also a major determinant of recycling method, where people without a high school diploma were the most likely to redeem beverage containers at a recycling centers and those with a bachelor's degree or higher were the most likely to use curbside services.

Table 1: Recycling by Income
Source: Intercept Survey conducted by the University of California, Berkeley research team.

Income	Processing Fee Recycler	Handling Fee Recycler	Total
Under $10,000	92 25%	47 22%	139 24%
$10,000-$25,000	70 19%	41 19%	111 19%
$25,000-$50,000	88 24%	46 21%	134 23%
$50,000-$100,000	57 15%	33 15%	90 15%
More than $100,000	29 8%	34 16%	63 11%
Prefer Not to Say	32 9%	15 7%	47 8%

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[5] https://www.census.gov/quickfacts/CA

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Income	Processing Fee Recycler	Handling Fee Recycler	Total
Total	368 100%	216 100%	584 100%

Black and Hispanic respondents were less likely to use curbside programs than others, and more likely to return material through recycling centers. This is at least partially due to the income effect described above because Black income is only 72% and Hispanic income 77% of the all Californians median income. Although disposal of beverage containers in the trash was not common, this largely did not vary across income groups. Rural residents were less likely to use curbside services (they are not frequently available in rural areas), and more likely to visit recycling centers infrequently, compared to respondents in urban area.

Recycling Center Hours

Recycling centers in convenience zones are required to be open for at least 30 hours per week as designated by CalRecycle. We found that the average recycling center is open in the earlier mornings when traffic at the supermarkets is slower and is closed or has limited hours on the weekend. To show the typical hours of operation, we sampled 19 recycling centers and their nearby supermarkets on a weekday and a weekend day. We recorded their open hours from CalRecycle data and their relative traffic frequencies from Google Analytics. We can see below that the recycling centers are open early on Wednesday and have limited hours on Sunday.
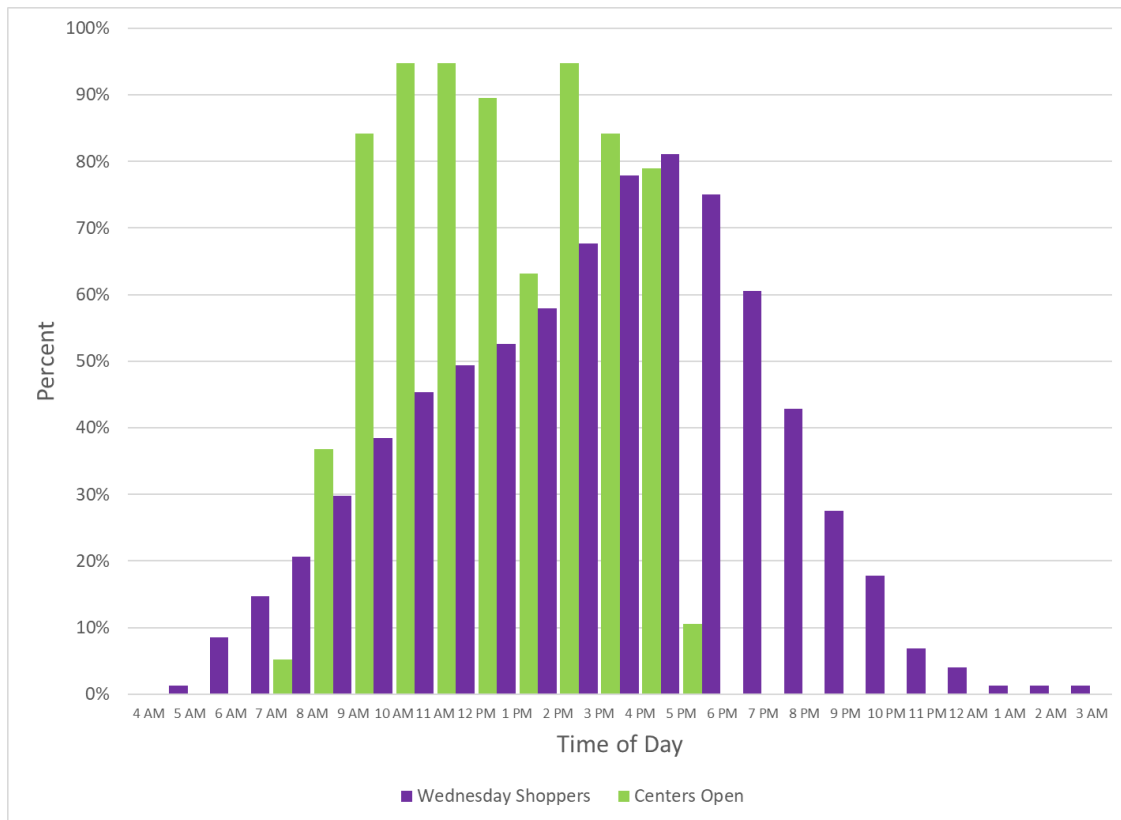
Figure 7: Wednesday Average Percent of Total Daily Shoppers and Centers Open

Wednesday is one of the busier days for supermarkets. The average supermarket sited recycling center will be open earlier in the day while most of the supermarket traffic comes in the afternoon and evening. The green bars show centers open during each hour and the purple shows the relative frequency of shoppers. Source: Intercept Survey conducted by the University of California, Berkeley research team and Google Analytics.

As seen above in Figure 7, typical hours for a recycling center (green) to operate on a weekday is from 8am until 5pm while the busiest time for supermarkets (purple) is from 1pm until 8pm; thus, not capturing the majority of shoppers' recycling.
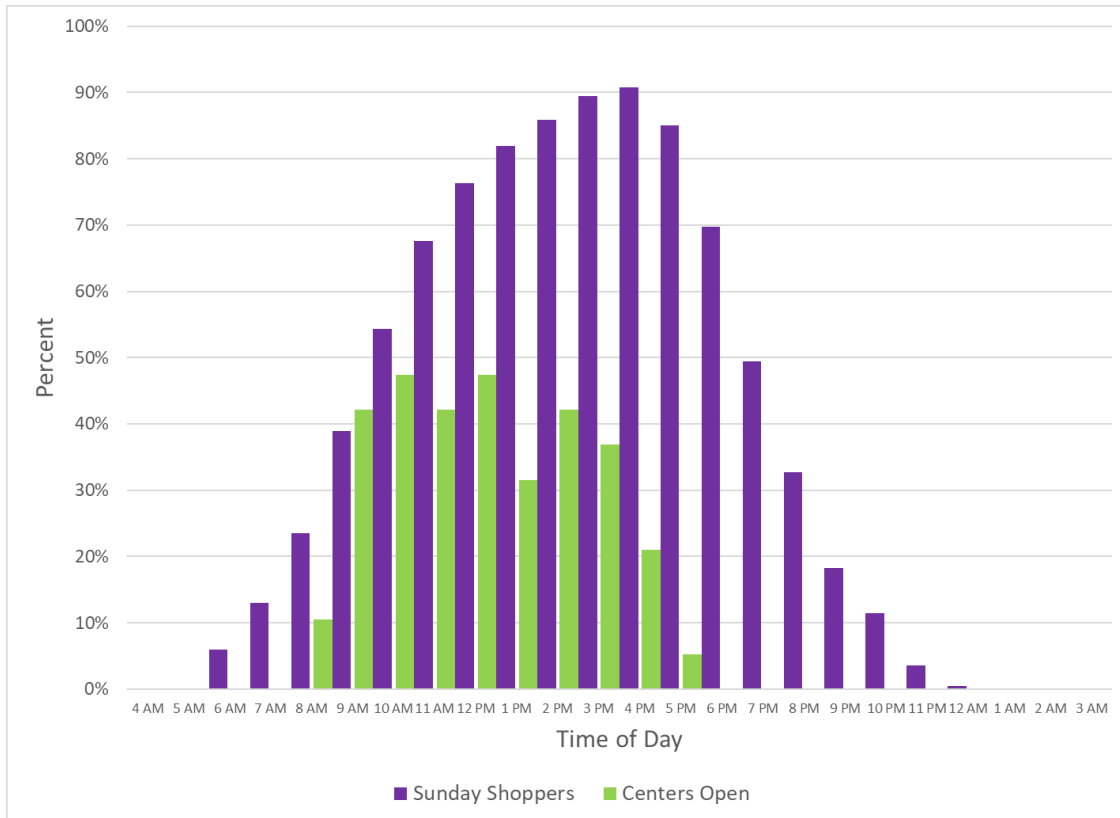
Figure 8: Sunday Average Percent of a Total Daily Shoppers and Centers Open

On the weekend, more shoppers will visit supermarkets on Sundays. Fewer than half of recycling centers are open on Sundays. The green bars show centers open during each hour and the purple shows the relative frequency of shoppers. Source: Intercept Survey conducted by the University of California, Berkeley research team and Google Analytics.

On the weekends, some recycling centers may not be open and supermarkets experience the most traffic from shoppers. Figure 8 shows fewer than 50% of recycling centers we sampled were open on Sundays with limited hours from 9am until 4pm. Supermarkets have the highest traffic from 9am until 7pm on Sundays.

Open times for centers was a major concern with consumers asked about convenience. Because of their limited hours, convenience centers are not convenient for many consumers.

Diverting Material

Curbside and Diverting

Diverting material occurs when the person or household that consumed the beverage is not the person redeeming the container. This typically occurs when a person takes the material out of a recycling or trash bin at the curb and brings the material to a recycling center to receive the CRV payment. People who partake in this activity are referred to as diverters. Figure 9 outlines the different pathways for a container to be disposed. There are three options for disposing of a beverage container: recycling center, curbside program, or trash. Any containers that were diverted from their original disposal method fall into two categories: good and bad diverting. 'Good' diverting is when containers are moved from trash bins or the ground to be recycled. One purpose of the Act was to clean up litter. 'Bad' diverting is when containers are moved from curbside bins. We want to encourage good diverting because it decreases the number of containers going to the landfill and helps the state of California achieve its AB32 goal to decrease greenhouse gases.
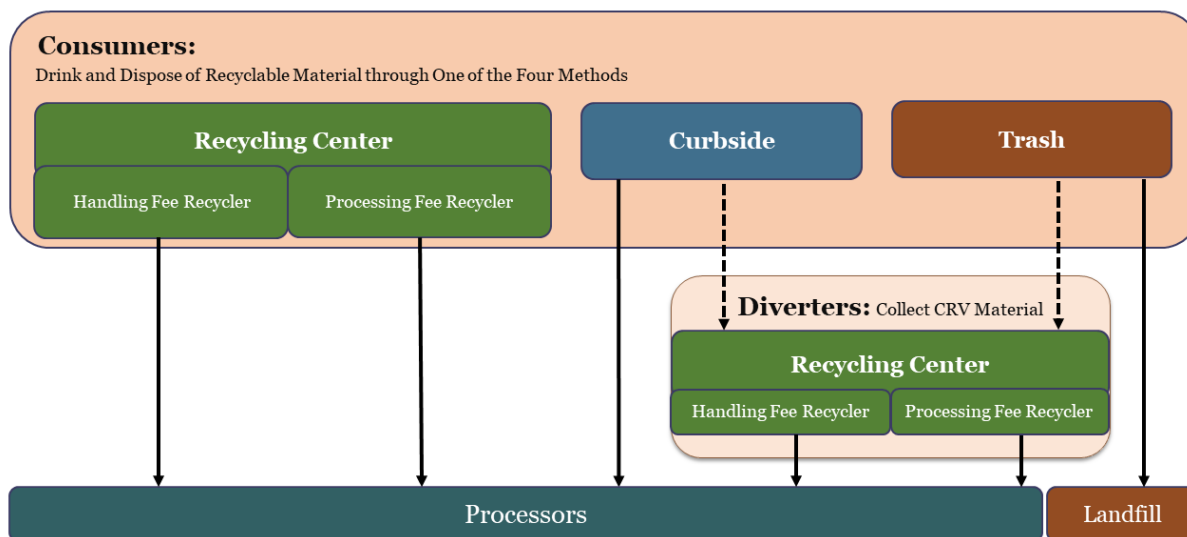
Figure 9: Recycling Pathways

There are three major options for people to dispose of their beverage containers: recycling centers, curbside providers, or trash.[6] If the consumer decides to recycle at a recycling center, then there are two types of center at which they can recycle: a handling fee center or a processing fee center. The consumers who recycle at a recycling center will receive a payment for their beverage containers while the consumers who recycle through curbside or put the containers in the trash will not receive the CRV payment. The curbside providers will receive the CRV payment for the containers collected via curbside. Any CRV eligible containers in the trash will be unredeemed containers. Some people will go through curbside and trash bins in neighborhood to collect CRV eligible containers and bring them to recycling centers to receive the CRV payment; this process is considered diverting containers.

The social desirability of bad diverting is complicated by curbside. Taking material from curbside decreases the number of containers and CRV collected by curbside but does not decrease the costs of collection very much. Diverting from curbside is a burden to the curbside provider. Curbside programs are supported by the CRV and by payments from the Fund including the Quality Improvement Program and direct subsidy. These two programs cost together $25 million per year. Curbside is also supported by AB341 that mandates commercial recycling and recycling in apartment buildings with five or more units. The requirements (AB939) for jurisdictions to implement programs to achieve 50%

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[6] There are also some dropoff programs.

diversion of all solid waste from disposal also makes it worthwhile for cities to have curbside. While the diverters do take considerable material from curbside, a collection of laws and other subsidies are a sufficient inducement to provide curbside service. Curbside is the most convenient way to recycle: it has no lines, travel time or open hours. However, it does not pay the user the CRV.

Returning to the social desirability of diverting. Besides the good diverting which keeps material out of the landfill or off the ground, the diverters are very impecunious people and earn a significant amount of money, for them, from this endeavor.

Diverters tend to make less than $10,000 and to be between 35-54 years old. The more diverted material people bring to the recycling centers, the less income their household typically declares. As the percentage of diverted material per trip to the recycling center decreases, the household income declared increases while the age remains relatively constant. This data confirms that people are recycling at centers to supplement their household income.

Movement of Material and Diverting

Approximately 40% of containers will be recycled at a center that is not located within the same zip code as the recycler; however, we must state caution when interpreting this data because zip codes sizes vary depending of the area of California.

Respondents from the intercept survey receive an average of $28.33 per visit to a recycling center with people collecting containers over an average of 44 days. We used the data from the frequency of center visits to construct the average redemption people receive per year. Based on the amount the individual received at the visit we observed and then calculated by the frequency of visits, we found the average yearly amount of redemption received by individuals is $1,244.41.

To understand diverting, we first looked at percentage of material claimed as not one's own. We found that people who return containers for their work place claimed 100% of diverting along with others who diverted more frequently. In Table 2 we can see the percentage of all containers recycled at recycling centers by the percent of material diverted.

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Table 2: Percent of Diverted Material
Source: Intercept Survey conducted by the University of California, Berkeley research team

	Percent of All Recycling Containers
100% Material Diverting	9%
75% Material Diverting	8%
50% Material Diverting	10%
25% Material Diverting	16%
0% Material Diverting	56%
Total	100%

When we look at the people who divert, we see that 11% of the people were 100% diverters, but they return less material per visit than other recyclers. As the percent of diverted containers per trip increases, the frequency a person visits a recycling center increases (Table 3). People who divert less than 50% of their collected material tend to frequent recycling centers monthly while people who divert over 50% of their material frequent recycling centers multiple times a week.

Table 3: Days Collected by Diverter
Source: Intercept Survey conducted by the University of California, Berkeley research team

	N	Percent	Days Collected		
			Mean	St. Dev	Median
100% Material Diverting	65	11%	8.2	15.5	1.0
75% Material Diverting	46	7%	28.1	60.8	3.0
50% Material Diverting	49	8%	30.9	33.0	30.0
25% Material Diverting	96	16%	58.3	88.5	30.0
0% Material Diverting	360	58%	58.9	69.2	30.0
Total	616	100%	48.9	68.5	30.0

Since those who return containers for their workplace are not frequent visitors to centers, looking at those who visit centers a couple of times per week gives a better picture of how much diverters return per visit. As seen below in Table 4, people with high frequency make up 16% of the total people visiting recycling centers bringing a median of 187.34 containers per visit. These recyclers are bringing about half of what a less frequent recycler is bringing per visit.

Table 4: Total Containers Collected by Frequency to Center
Source: Intercept Survey conducted by the University of California, Berkeley research team

Frequency	N	Percent	Total Containers		
			Mean	St. Dev	Median
3 Day or Fewer	98	16%	370.66	531.08	187.34
More than 3 Days	530	84%	493.51	506.16	346.74
Total	628	100%	474.34	511.64	308.32

Respondents who collected material over a longer period of time receive a higher redemption payment per visit with most of the payment coming from containers their household consumed. As seen in Table 5, people who frequent recycling centers every three days or fewer receive a median redemption payment of $10.89 per visit while people who are less frequent recyclers receive a redemption payment of $19.40 per visit. Frequent visitors will receive a lower redemption payment per visit with a higher proportion of the containers they are redeeming coming from sources outside of their household.

Table 5: Total Redemption Payment Collected
Source: Intercept Survey conducted by the University of California, Berkeley research team

Frequency	N	Percent	Total Redemption		
			Mean	St. Dev	Median
3 Day or Fewer	98	16%	19.79	25.18	10.89
More than 3 Days	530	84%	28.28	30.03	19.40
Total	628	100%	26.95	29.47	17.22

With a total of 298,000 containers in the sample returned to recycling centers, we find the percentage of material that is returned via different diversion pathways.

Table 6: Percent of Diverted Recycling
Source: Intercept Survey conducted by the University of California, Berkeley research team

Diverting	Percent of All Recycling Containers
From Both	6%
From Recycling Bins	1%
From Trash Bins	19%
Total	26%

We see that 26% of all recycled material comes from containers collected from recycling and trash bins. The majority of containers that were diverted come from trash bins (19%).

Table 7: Recycling by Frequency to Center
Source: Intercept Survey conducted by the University of California, Berkeley research team

Frequency	Percent of All Recycling Containers
3 Day or Fewer	12%
More than 3 Days	88%
Total	100%

We see here that 12% all containers brought to recycling centers are received by frequent recyclers.

Table 8: Diverted Curbside Containers
Source: Intercept Survey conducted by the University of California, Berkeley research team

Diverting	Total Containers	% of Total Curbside
Recycling Bins Only	3,873	12%
Recycling Bins and 50% of Both	12,362	31%

Intercept survey participants stated that their center returned material contained 1% of material that they had diverted from curbside. Curbside, however, is only about 9% of total collections (we have averaged curbsides percent across materials for June

2015). On percent of center returns is 12% of what would originally have been placed in curbside bins. Therefore, our lowest estimate of the diversion from curbside is 12%. If half of the material categorized as mixed between trash and curbside was curbside, then the percent diversion was 31%.

When asked in the intercept survey if people diverted material from trash and/or recycling bins, 71% of people only diverted from trash bins, 9% of people diverted only from recycling bins, and 20% of people diverted from both trash and recycling bins.

Table 9: Total Redemption Payment by Source of Diverting
Source: Intercept Survey conducted by the University of California, Berkeley research team

Diverting	N	Percent	Total Redemption Payment		
			Mean	St. Dev	Median
From Both	41	20%	22.61	21.04	12.10
From Recycling Bins	19	9%	11.99	9.34	10.93
From Trash Bins	144	71%	27.99	26.44	16.85
Total	204	100%	24.98	24.37	15.41

People who divert material only from trash bins bring in a median of 313.19 containers per visit and receive a redemption payment of $16.85 per visit. The median days to collect containers from trash bins is 14 while the median for recycling bins and either trash or recycling is 3 and 1 respectively. This is logical because recycling bins in many areas of California are sorted, therefore, making it easier for a person to collect containers from the curbside bin while trash bins require a more thorough search for containers.

Section 2. Evidence from Econometric Models on Cost and Payments

In this section, we use econometric methods to quantify the costs of convenient recycling. We focus on the number of centers in operation and the amount of material returned as these are the variables related to convenience and cost that can be econometrically modeled. The section begins with a detailed description of the payment structure and the calculation of processing fees. The section shows how center average revenue is heavily influenced by aluminum scrap value. The next section discusses handling fees and relates these fees to the number of operating handling fee centers. When handling fees were decreased due to the 2008 change to a cost-based methodology, the number of centers fell. This result is verified in an econometric model.

Payment Structure

Recycling centers have three major sources of revenue: scrap value, processing payments, and handling fees. The structure of these three payments makes center revenue heavily dependent on the scrap price of aluminum, but not of glass or other materials. The use of container-weighted averages in calculating costs and therefore payments makes the centers of moderate size break even while those that are small lose money and those that are large make money.

Both handling and processing fee centers receive the processing payment, while only handling fee centers receive the handling fee. In addition, there is an administrative fee that is very small, 1.25% of CRV for both types of centers. It is not consequential to the following discussion. The source of some of these funds is beverage manufacturers while the State Fund is the source of the rest of the payments. The Fund is able to make these and other payments because it keeps the redemption value for unredeemed containers. The scrap value is determined by world markets for scrap materials, which in turn determines what processors are willing to pay for scrap. The Fund expends $10 million per year on plastics market development. In economic terms, this is a sales expense to increase the market and price of plastic scrap. The Fund also has a Quality Improvement Program ($15 million), paid to curbside and drop-off programs to pay for these operators to make more marketable loads of recyclable material. Other than these sales expenditures, CalRecycle has little or no ability to control scrap values.

Processing Payments

The formula for handling and processing payments depends upon cost. CalRecycle conducts a survey of recycling center costs every two years. This survey results in a container weighted average cost estimate. Being container weighted, the larger centers, which are known to have lower costs, are weighted more than the smaller centers. That means that the cost estimate will be lower than the costs of more than half the centers. The cost estimate measures the average per container cost, not the cost of an average center. The processing payments per container are calculated in the following manner:

$$Processing\ Payment \\ = (Cost\ of\ Recycling \\ * Reasonable\ Financial\ Return \\ * Cost\ of\ Living\ Adjustment) - Scrap\ Value$$

If the processing payment is less than zero, then no payment will be distributed. That is the case for aluminum.

For the other materials, there is a processing payment. From the formula above, one can see that, in principle, a decrease in scrap value is entirely offset by an increase in processing payment. The system is designed to make the processing payment plus the scrap value equal to the cost of recycling (with financial return and inflation.)

In practice, it takes time for the processing fee to be reset after a decrease in the scrap value of glass, PET, HDPE etc. The time it takes the processing fee to adjust is by no means the greatest challenge in the recycling system.

Processors are in the business of collecting material from centers and forwarding it to an ultimate end user. They are paid the world scrap price for their material. If that price is very low, they will not be able to pay their expenses and they will cease to operate. So long as the scrap price they receive is larger than their expenses, they will continue to buy material, possibly at a price of zero, from centers.

The aluminum scrap price poses a special challenge for the system. The scrap price has been high enough so that there is no processing payment for aluminum. As a result, the revenue a center earns from aluminum is the revenue it earns by selling processors scrap aluminum. Because the scrap price of aluminum is higher than the costs of recycling allocated to aluminum, centers achieve a profit on aluminum that they do not achieve on any other material. This profit is what makes it financially feasible for centers with costs higher than the container weighted average cost to stay in business. In practice, it is the

aluminum scrap value that financially floats the smaller centers. With falling scrap prices, revenues in the recycling business fall, and centers, particularly high cost centers are closing.

Aluminum scrap values are typically high, so there have been no processing payments on aluminum. It is more cost effective for companies to use aluminum scrap rather than process aluminum from raw inputs, which leads to a high scrap price for aluminum. Since there is no processing payment for aluminum, recycling centers are completely exposed to the fluctuation of the aluminum market. Aluminum prices fell in 2008 due to the global financial crisis, economic slowdown, and lower aluminum demand from China. This fall in prices caused recycling centers to experience lower revenues. Figure 10 shows the decline in aluminum scrap value and how recycling center revenues are closely related to aluminum values. Figure 6 shows the average revenue per container and the aluminum scrap values from 2005 to present. Especially since 2008 when the methodology for computing processing fees became rigorously cost based, the figure shows that center revenue per container and aluminum scrap value closely track each other. Generally, scrap values fell sharply in 2008, rose again to 2011, and with some ups and downs have declined since. From the 2011 peak to 2016, the values of both scrap and average revenue have declined by one penny, which is about 1/3 of their value.
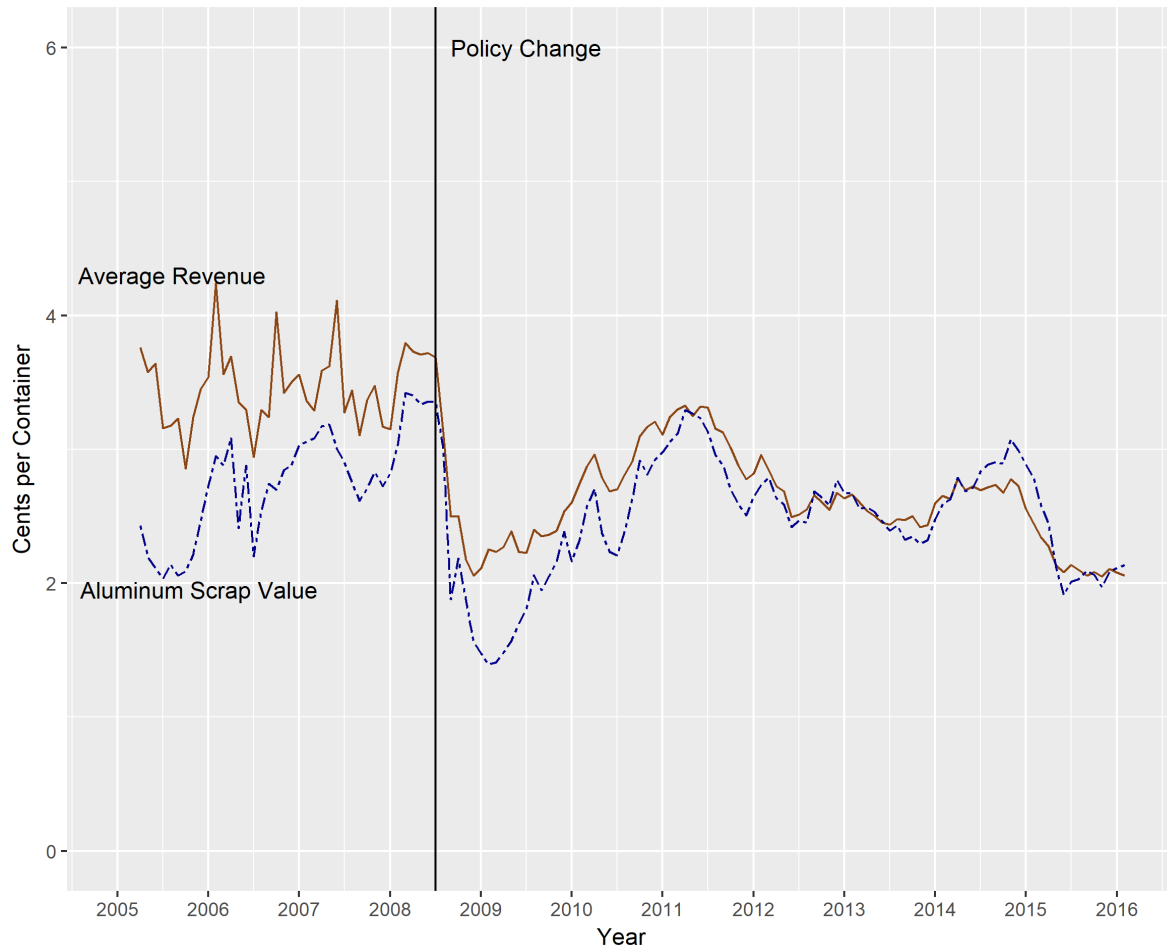
Figure 10: Aluminum Scrap Value and Average Weighted Revenue for Processing Fee Recycling Centers

The aluminum scrap value has fluctuated over time. In 2008, aluminum scrap value fell[7] due to the global financial crisis and economic slowdown. China has been an important buyer of these commodities and in 2008 there was a slowdown in their demand for aluminum. As seen in this Figure above, revenues[8] for recycling centers closely follows the aluminum market scrap value price. Sources: CalRecycle Data received July 2017

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[7] http://www.nytimes.com/2008/10/14/business/economy/14commodities.html
[8] Revenue is defined as the income a recycling center receives from the state and from selling scrap

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Handling Fees

In addition to receiving processing payments, handling fee centers[9] located in convenience zones receive an additional subsidy from CalRecycle in the form of a handling fee. The convenience center mandate and the handling fees were part of the original Act and were designed to produce consumer convenience in recycling. Consumers were expected to return their empty containers as part of a supermarket trip to buy full containers. The payments were necessary because small-scale recycling centers in supermarket parking lots do have higher costs of operation than large scale centers operating in an industrial environment. Data on costs and center size bear out that these centers are more expensive to operate.

At times, the funds for these handling fee payments from CalRecycle are low or unavailable, so the amount paid to recycling facilities may be decreased or not distributed. As outlined in AB7, this was observed in 2009 when funds were unavailable for handling fee payments and decreased for processing fee payments. AB7 restored these payments.

Handling fees were initially intended to encourage more convenient recycling opportunities for beverage consumers. While there are some small centers that are in business that would have been operating at a loss without the subsidy, the existence of these centers does not necessarily imply an increase in convenient access to recycling. Earlier in this report, we discussed hours open, which respondents thought was an important attribute of convenience, and is not matched between shopping hours and handling fee center open hours. Nor are the users of handling fee centers overwhelmingly concerned with their being near supermarkets, of people surveyed in the AmeriSpeak survey only 17% thought colocation was important.

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[9] Recycling centers that receive the handling fee must locate within the half mile radius around a supermarket with $2 million or more in revenue. The recycling facility must also be the only center within the convenience zone. If a recycling facility does not locate in the convenience zone then all beverage dealers within the zone must pay $100 per day or redeem the CRV bottles in the store.

Revenue Relative to Costs by Size and Type of Center

Every two years, CalRecycle collects cost information on recycling center operations in California. Using the cost of operating data from the CalRecycle reports, we utilize the cost of recycling by center size (small, medium, and large)[10] and type (handling fee and processing fee centers) to understand how the cost of operating relates to average revenues. The revenue for each type of recycler is calculated by summing the processing payment, handling fee (if a handling fee center), and scrap values. The processing payments only apply to plastic and glass beverage containers. As discussed before, there is no processing payment for aluminum due the historically high prices centers receive for selling their aluminum scrap.

As seen in Figure 11, as recyclers increase in size, their cost per container decreases. That is to say, recycling centers experience economies of scale. The profit for both handling fee and processing fee centers fluctuates with aluminum scrap value. Note that without the one cent handling fee, revenue[11] for small handling fee recycling centers would always be below the cost of operation. The 2008 policy change permanently changed the handling fee from 1.75 to a cost-based number that was 1.01 after the change and has fallen since then. At the same time, the world scrap markets crashed. These events placed small handling fee centers below the financial viability mark. Many of these centers exited the business, despite the convenience zone mandate. By 2011, these smaller handling fee centers returned to financial viability. Now in 2016, however, they are again, on average, in the red. This differs from the processing fee centers which, on average, operate in the black.

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[10] The size of a recycling center is specified by the volume the center takes in. The distribution is as follows:

Type of Facility	Small	Medium	Large
Handling Fee Center (million containers)	Small: x<4.35	Medium: 8.05>x≥4.35	Large: x≥8.05
Processing Fee Center (million containers)	Small: x<10.8	Medium: 21.9>x≥10.8	Large: x≥21.9

[11] Revenue is defined as the income a recycling center receives from the state and from selling scrap
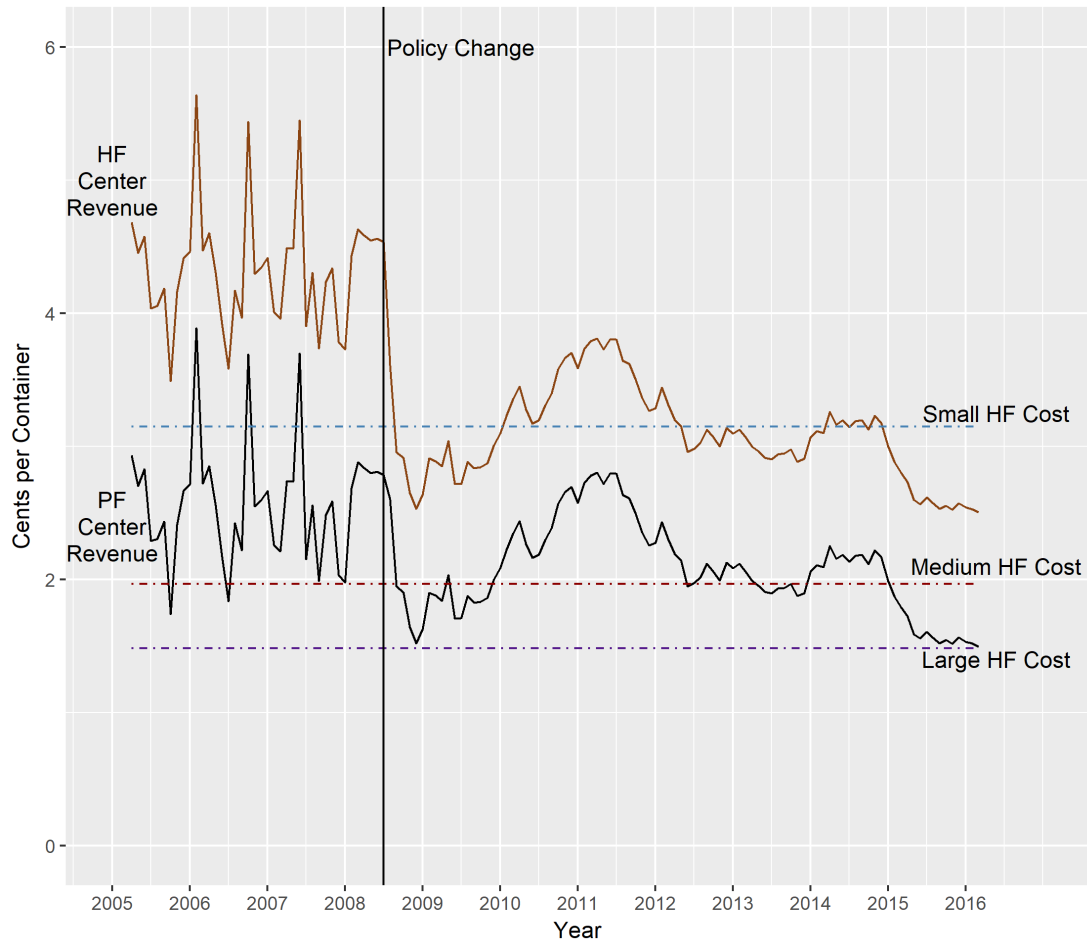
Figure 11: Monthly Weighted Average Profit for Handling Fee Centers

Recyclers experience economies of scale, average costs decrease with the increased processing of containers. As seen above, the smallest centers (strata 1) operate at the margin. If handling fees decrease then these centers would likely cease to exist because it would no longer be profitable to operate. Handling fee payments switched over to the new cost-based methodology in July, 2008, denoted by the vertical black line. Cost per container comes from the 2016 cost survey conducted by CalRecycle which separates the handling fee centers into small, medium, and large stratum. Handling fee (HF) centers and processing fee (PF) centers have different revenues. Using a combination of processing payments, handling fees, and scrap values, we calculated the weighted average revenue per container for each type of recycling center. Source: CalRecycle Data received July 2017 and 2016 cost surveys

Change in Center Types and Numbers

Recycling opportunities increased from 2000 until 2012 even with the change in handling fee payments. We show in this section that this increase comes mostly from processing fee centers while the number of handling fee centers plateaued following the change in handling fee structure in 2008 (Figure 14). In Figure 16, we see that this is felt mostly by the small handling fee centers.

Figure 8 shows that despite the downturn in revenues and concomitant reduction in the number of centers, the number of centers is still very much in the historical range. The peak and trends in the number of centers corresponds very well to the average revenue peaks and trends which is shown in Figure 9 for processing center returns and total number of recycling opportunities. Table 10 shows that with a one cent increase in revenue, processing fee centers will increase by 50 centers and handling fee centers will increase by 72 centers.
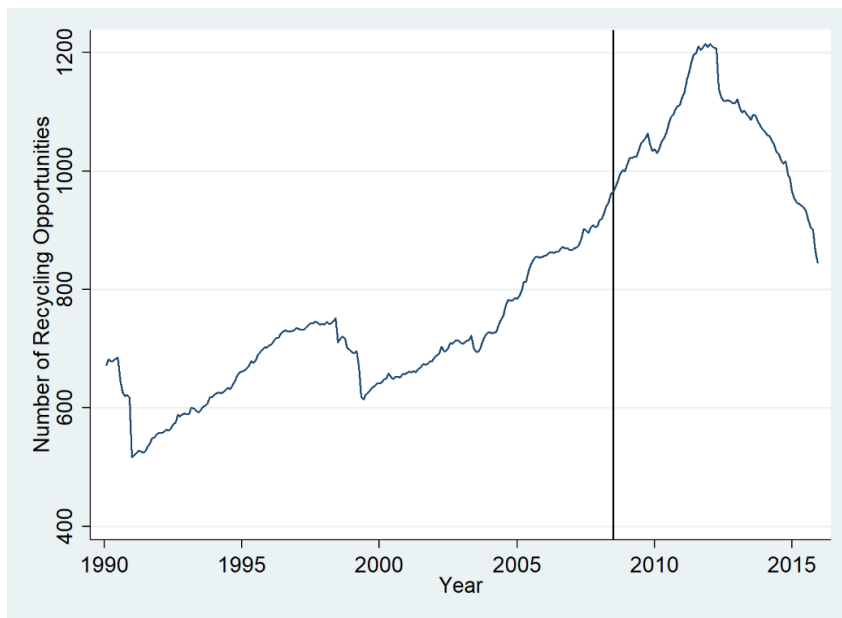

Figure 12: Recycling Opportunities in California

The total number of recycling opportunities in California continued to increase following the policy change in 2008. Prior to the policy change, the number of recycling opportunities in California was increasing. Source: CalRecycle Data received July 2017

Not all types of centers prospered after the 2008 reform. We observe that handling fee recycling opportunities and processing fee recycling opportunities were increasing at a similar rate prior to 2008 when legislation was implemented to restructure handling fee payments. While the number of total recycling opportunities had been steadily increasing, the number of handling fee recycling opportunities has been decreasing since the change in legislation. Keeping small handling fee recycling centers would be very costly to the state of California. While the decrease in the number of centers may negatively impact the consumers by decreasing recycling opportunities, consumers will continue to recycle and will not greatly reduce recycling rates given consumers' willingness to travel to recycling centers.
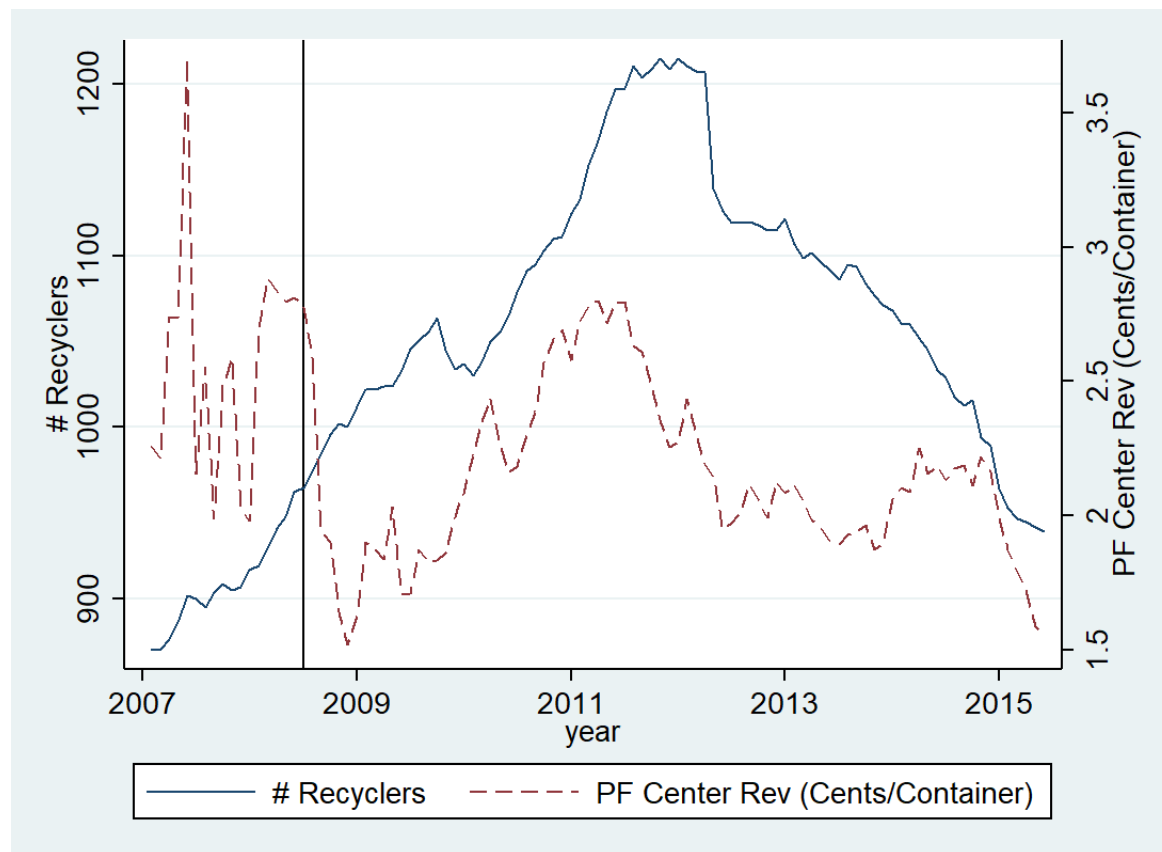

Figure 13: Recycling Opportunities in California and Financial returns, 2007-2012

The increase in recycling opportunities post 2009 was propelled by high revenues. Source: CalRecycle Data received July 2017

Table 10: Regression of Recycling Opportunities on the Center Revenue per Container
Source: CalRecycle Data received July 2017

VARIABLES	(1) PF Centers	(2) HF Centers
PF Center Revenue	49.71***	
	(8.750)	
Year	2.303***	-2.262***
	(0.228)	(0.101)
HF Center Revenue		71.73***
		(8.247)
Constant	-893.6***	1,626***
	(142.2)	(68.52)
Observations	71	71
R-squared	0.673	0.806

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10 shows a regression of the number of recycling opportunities on the center revenue per container and a linear trend by center type. Data are 2009 to 2015.

Prior to the policy change in 2008, handling fee and processing fee recycling opportunities were almost equal, but following the restructuring of handling fees, small handling fee centers closed and the number of handling fee recyclers plateaued while the number of processing fee recyclers continued to increase. When one looks at the small handling fee centers the picture is more pronounced.
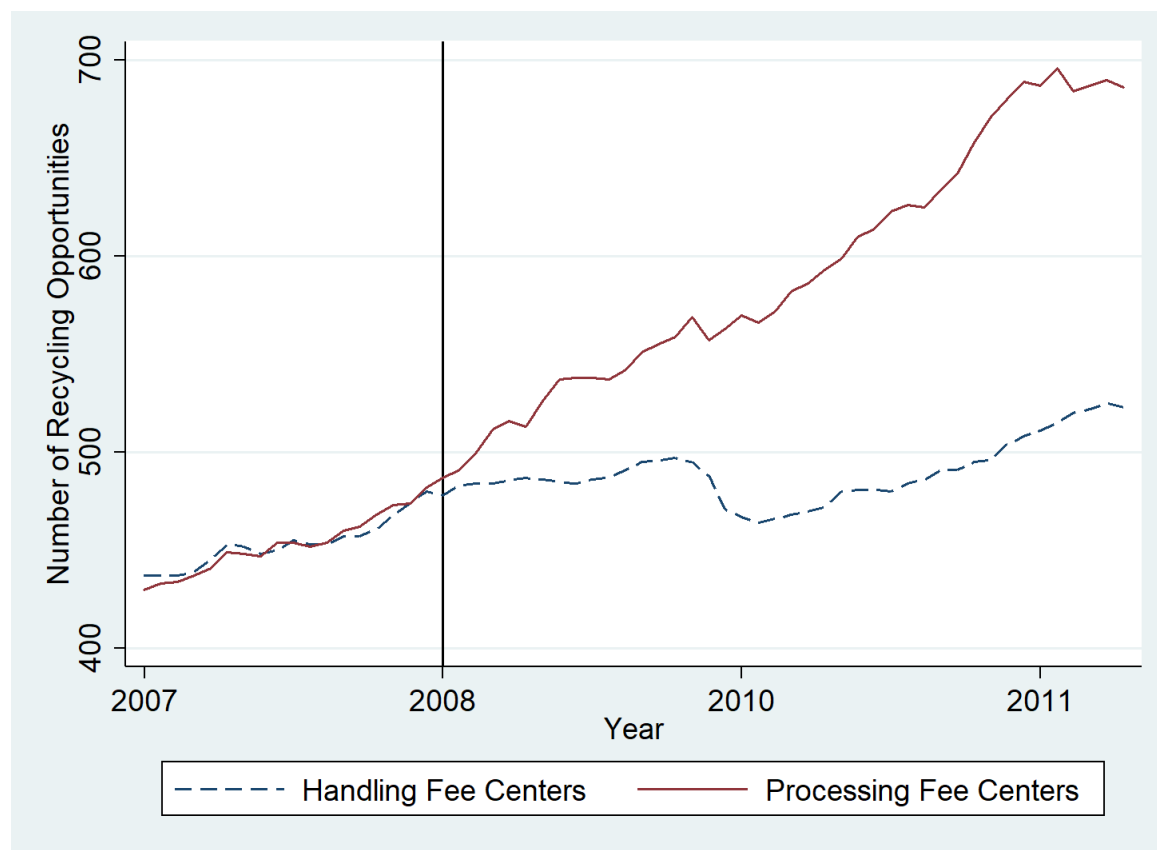
Figure 14: All Handling Fee and Processing Fee Centers

The handling fee and processing fee recycling opportunities were following the same trend prior to the 2008 policy change. After the 2008 policy change that restructured handling fees, the number of handling fee recycling opportunities became stagnate while the number of processing fee recycling opportunities continued to grow. Source: CalRecycle Data received July 2017.

Size Composition of Centers and the 2008 Reform

We can also show further how the ratio of handling fee to processing fee opportunities has changed after the 2008 reform by graphing the percentage of recycling opportunities by type over time. Prior to 2008, the proportion of processing fee and handling fee centers were close to equal (50-50) in the makeup of recycling opportunities. After 2008, the percentage of handling fee recycling opportunities declined to a 60-40 makeup of processing fee to handling fee recycling opportunities respectively.
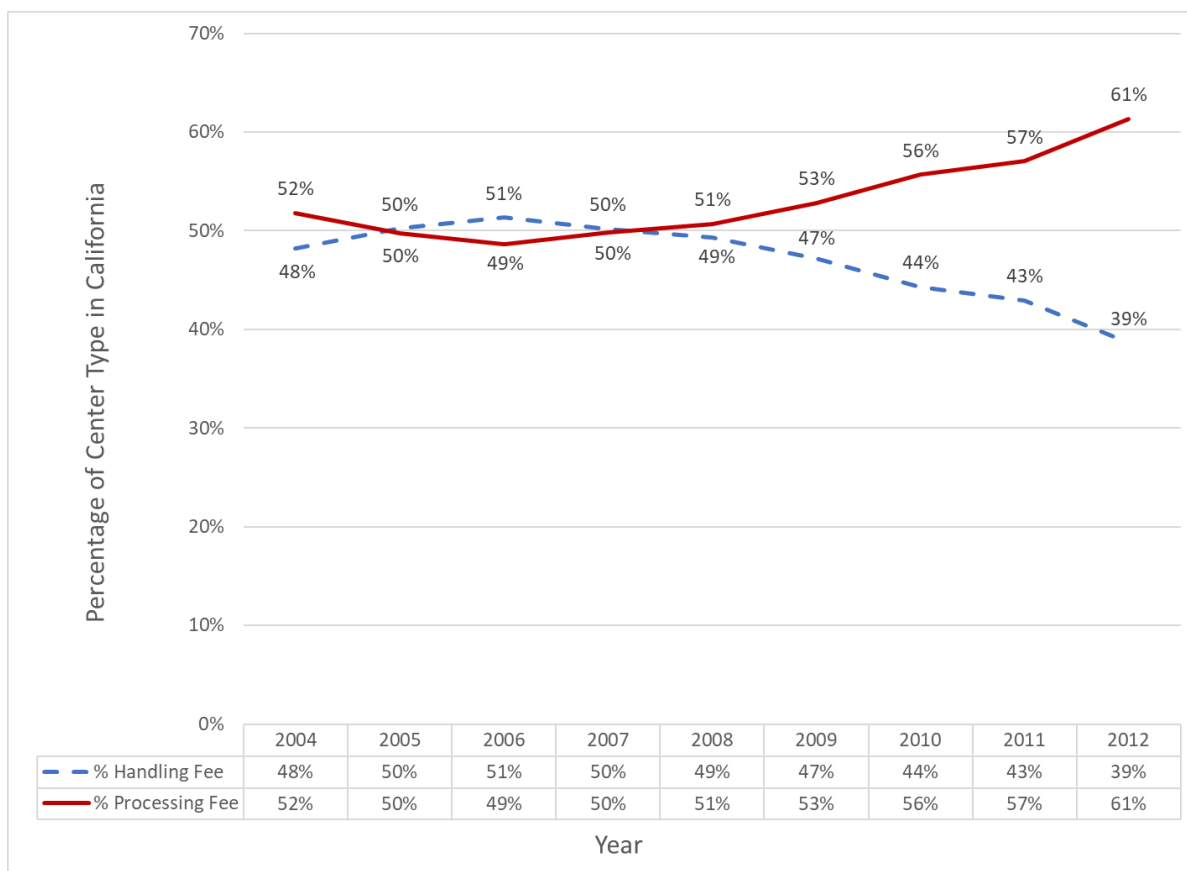
Figure 15: Percentage of Recycling Centers by Type

There are two types of recycling centers in the state of California: Handling Fee Recycling Centers and Processing Fee Recycling Centers. The two different types of centers receive different payments. A handling fee center receives handling fees, processing payments, and scrap values while a processing fee center receives processing payments and scrap values. After the 2008 policy change when handling fee were no longer capped and decreased in cents per container, the number of handling fee centers decreased in numbers. Source: CalRecycle Data received July 2017

The change in handling fee recycling opportunities is primarily due to the decline in the number of small handling fee recyclers. These smaller centers were no longer profitable due to the lower handling fees and center monthly cap (see Figure 11). We see in

Figure 16 how the proportion of medium and large handling fee centers have remained relatively constant while the small proportion of handling fee centers has fallen.
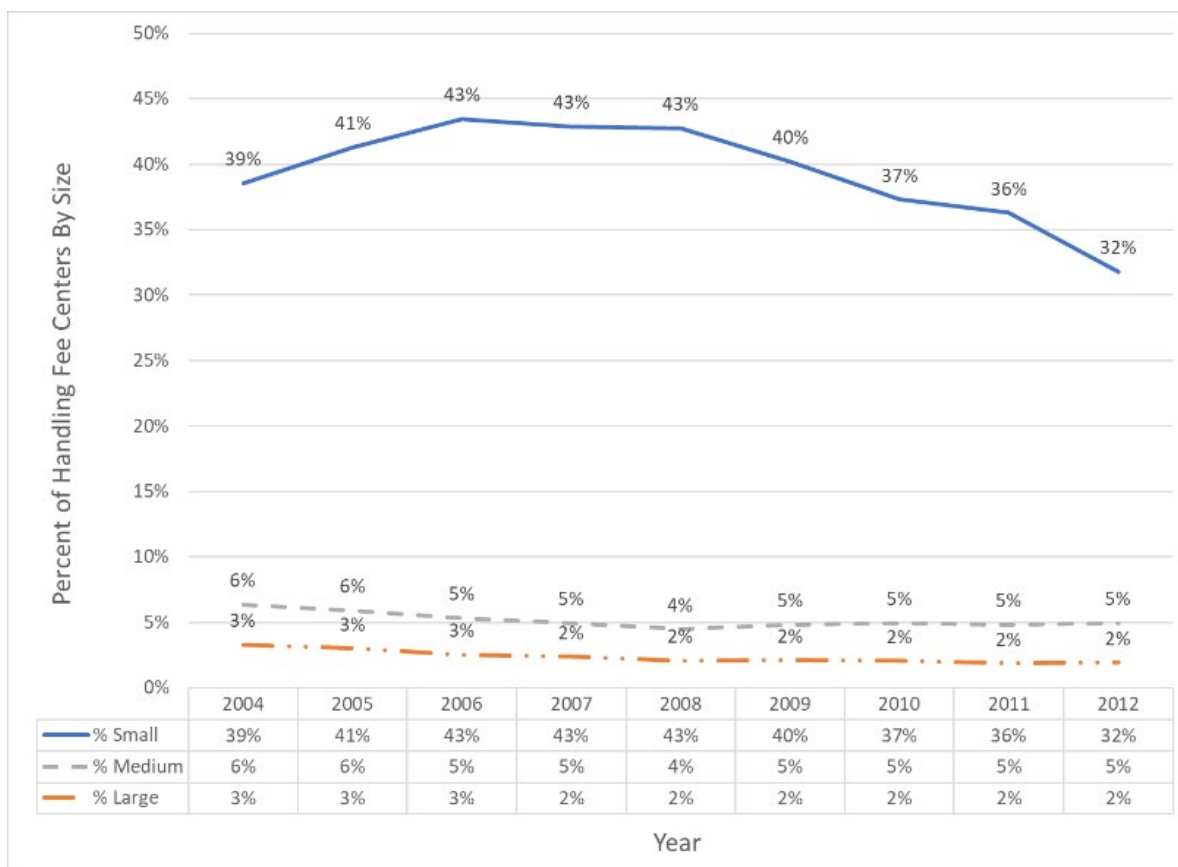
Figure 16: Percentage of Handling Fee Recycling Centers by Size Relative to all Recycling Centers in California, 2004 – 2012

The number of handling fee recycling centers decreased over time. The proportion of medium and large handling fee centers relative to total handling fee centers remained fairly constant for the 2004-2012 time period. We can conclude that the main force driving the decrease in handling fee centers comes from a decrease in the number of small handling fee centers. Source: CalRecycle Data received July 2017

We tested this hypothesis that the reform in 2008 caused the decline in the small handling fee centers. The test compares the change in small handling fee centers to small processing fee centers and finds that 111 small centers exited the industry because of the 2008 reforms. The reform caused handling fee centers to be paid 0.75 cents less, so a one cent change in the fee results in 148 fewer centers. (The estimate comes from a difference in difference model and is statistically significant at the 99% level)

This decline in smaller centers continues to lower the handling fee payment because of the structure of the two-year cost survey. With each small high-cost handling fee recycling opportunity that no longer operates, centers will observe a lower handling fee payment (due to lower average cost of operating centers). Ultimately, this could mean that small handling fee recycling opportunities will no longer be in available, but, as see in Figure 12: Recycling Opportunities in California, current evidence shows that recycling center opportunities have not decreased.

In terms of the total cost of operating the recycling system, the demise of centers with a cost of about 3 cents and rise of lower cost centers makes the system cheaper to operate. The demise of handling fee centers takes pressure off the Fund as the Fund no longer has to pay handling fees.

In terms of consumer convenience, 93% of consumers drive. They do not report a change in convenience even though supermarket sited opportunities have decreased. This is likely because once in the car, the convenience of a supermarket parking lot is no greater than that of a free-standing recycling center. There is also the matter of hours open. The lost handling fee recycling centers did not have hours open that closely matched shopping hours.

The Effect of CRV, Number of Centers, and Curbside on Recycling

Increases in the number of recycling centers, the CRV rate, and the availability of curbside pickup increase the quantity of bottles and cans returned. We use administrative data from CalRecycle and publicly available demographic data to quantify these effects. We augment this with additional analysis using the AmeriSpeak survey, looking at consumers' stated disposal preferences, and using simulations to evaluate changes in the number of handling fee centers and a 100% change in CRV on recycling. While the administrative data can provide information about the aggregate effects of various policy modifications on recycling behavior, the AmeriSpeak data can help us understand the underlying heterogeneity in recycling behavior among different consumers.

Aggregate Trend Analysis of Centers on Recycled Material
The data are analyzed at the county level by month. A regression model is used to show the dependence of the shares of recyclable material returned in recycling centers, and curbside programs as a function of CRV, the number of centers, and the extent of

curbside pickup. The regression model also includes control variables for the month of year, county, temperature, and county demographics.

The regression model is limited to time periods in which a substantial quantity of the total recorded state returns are accounted for in the data of individual center returns.

The key results from this exercise evaluated at June 2015 are:

An increase in CRV of 1 cent would

- Increase aluminum recycling center material by 2%, nearly all of it at the expense of curbside or importation of out of state and out of program aluminum.
- Increase glass recycling center material by 0.69%, of which 65% would come from trash.
- Increase PET recycling center material by 1.3% of which 80% would come from trash.

An increase of 100 recycling center material centers would increase recycling only slightly, most of the increase being reallocation from curbside. The net increase is estimated at
- Less than 1% for aluminum
- 1.3% for glass
- 4% for PET

Increasing CRV for glass and PET by 3 cents would increase the value of their unredeemed containers, which accrue to the Fund by
- 52% for glass
- 39% for PET

The remainder of this section explains the data and methods, as well as gives more detail on the results and how they are calculated.

Data

To construct the share of each material that is collect in recycling centers and in curbside, three types of data are used: data on the volumes of recyclable materials collected in recycling centers, data on the volumes of recyclable materials collected by curbside, and the total sales of covered containers. These are the variables that we explain as a function of the variables of interest, those variables that are determined within the program, and a

set of control variables, which give some information on the demographics that lead to recycling. The data are collected by county and by month. We now describe each of these types of data.

Shares

To compute the share of a counties returns, in a pathway (recycling centers, curbside) we find the number of containers returned in a county in a month in a pathway and divide that by the state-wide sales of containers. The data needed for this calculation are:

1. Handling Fee Center volumes aggregated to the county level and converted to containers at the CPP rates. Source: CalRecycle.
2. Processing Payment Center volumes aggregated to the county level and converted to containers at the CPP rates. Source: CalRecycle.
3. Curbside volumes reported as returned to recycling centers is aggregated to the county level and converted to containers at the CPP rates. Volumes that are returned to processors are at the state-wide level and have been allocated to counties based on the reported county curbside share, which are then converted at the CPP rate. Curbside volume by county is the sum of the returned to centers and returned to processors. Source: CalRecycle
4. Sales are the total reported sales of eligible beverages in container units. Source: CalRecycle

The residual share is what is collected in minor programs, what is sent to trash, and the containers brought into the state without paying into the Fund. There is also some reallocation from one month's sales to another month's returns.

Variables of Interest

These are the variables in the regression that determine recycling shares and are important in managing the recycling program.

- Real CRV. The CRV in June 2016 dollars. Source: CalRecycle
- Number of recycling centers. The total of the number of handling fee and processing fee centers certified in the county. The regressions use the number of recycling centers lagged by one month. Source: CalRecycle
- Number of Curbside programs. The regressions use the number of curbside programs lagged by one month. Source: CalRecycle

Control Variables

These variables help determine recycling shares but they are not things that CalRecycle can change in its management of the recycling program.

- Mean Temperature at Recycling Centers. Source: Prism, University of Oregon
- County Unemployment Rate. Source St. Louis Federal Reserve Bank's FRED database
- County Mean Family Income. Source US Dept. of Housing and Urban Development Data
- County Population. Source RAND Corporation
- County Population Density. Source California State Association of Counties
- Percent of Multi-family housing by Count. Source California Department of Finance Population and Housing Estimates

The regressions use a differencing technique that removes the effect of calendar month and of county. This is equivalent to adding a fixed effect for each county and for each month (e.g. January, February).

The time period for this econometric model was January 2005 to June 2016. However, there were many months where the data by center was very incomplete and those months were omitted.

The Method

The recycling shares are explained as a logistic function of the variables of interest and the control variables. We linearize the logit model by taking the ratio of a share (e.g. for aluminum, percent of total state sales returned in curbside, in Alameda County in June 2015) to the share not returned anywhere in the state. This transformation of the shares is due to Steven T. Berry's 1994 paper entitled *Estimating Discrete-Choice Models of Product Differentiation*.[12] The ratio of shares is used in a linear regression with the explanatory variables being those listed above as either variables of interest or control variables.

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[12] Steven T. Berry. The RAND Journal of Economics. Vol. 25, No. 2 (Summer, 1994), pp. 242-262

The regression coefficients tell the effect of a change of one unit in any of the explanatory variables. For policy purposes, we are interested in the effect of a change of one unit in an explanatory variable on the share recycled in a pathway. For instance, we want to know if CRV were increased by one cent how much the share of aluminum returned at recycling centers would increase. These effects are called the marginals. The marginal move in the same direction as the coefficients from the regressions and we will first discuss the coefficients.

The results of this regression for each material are in Table 11. The table has one column for each material and one set of rows for each explanatory variable. The first coefficient in the table is in the aluminum column: 2.198. The three stars indicate that it is significantly different from zero at the 99% level. The number in parenthesis underneath (0.105) is the standard error of this estimate. The table shows that an increase in CRV and in the number of centers and programs all increase the recycling of every material. Except in the case of the number of centers in the aluminum column, every one of these variables has high statistical significance. Of the control variables, it is interesting that a county with higher mean family income has higher recycling of all materials except glass. Counties with large numbers of apartment buildings recycle substantially less plastic.

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Table 11: Regression Output
Sources: CalRecycle Data received July 2017

| | Dependent Variables | | | |
| | Ratio of Shares | | | |
	(AI)	(GI)	(PET)	(HDPE)
Real CRV in June 2016 Dollars	2.198***	1.629***	1.757***	1.900***
	(0.105)	(0.105)	(0.094)	(0.106)
Number of Recycling Centers (Lagged One Month)	0.012	0.060***	0.071***	0.049***
	(0.010)	(0.008)	(0.007)	(0.010)
Number of Curbside Programs (Lagged One Month)	0.057*	0.224***	0.264***	0.222***
	(0.032)	(0.026)	(0.024)	(0.031)
Mean Temperature at Recycling Centers	-0.025	0.013	0.075**	-0.008
	(0.033)	(0.036)	(0.035)	(0.049)
County Unemployment Rate	-0.115***	-0.120***	-0.096***	-0.261***
	(0.033)	(0.039)	(0.031)	(0.052)
County Mean Family Income	0.546	-1.772	5.827*	13.187***
	(2.888)	(3.135)	(3.149)	(4.559)
County Population	1.553	1.044	7.306***	-1.545
	(3.096)	(2.368)	(2.198)	(2.482)
County Population Density	-12.185	5.375	5.952	7.158
	(13.634)	(20.07)	(25.18)	(24.93)
Percent of Multi-family Housing	-79.279	13.098	-136.260***	-137.632**
	(54.597)	(57.97)	(49.88)	(63.71)
Observations	10100	10,100	10,100	10,100
R2	0.367	0.277	0.335	0.399
Adjusted R2	0.362	0.272	0.330	0.395
Residual Std. Error (df=10028)	6.855	7.024	6.445	9.303
Note:	*p<0.1;	**p<0.05;	***p<0.01	

The formula to convert from the coefficients to the marginal effects depends on the current share of the material that is recycled. We will explain using CRV for aluminum. The experiment that is of interest is to increase the CRV by one cent. This directly changes the amount returned at recycling centers. For each county we find the share (of the state-wide sales) that are returned at recycling centers. Call that share-county. We then calculate share-county multiplied by (1 – share-county). We do that for every county and sum up over all counties. The result of this calculation is a number slightly less than the recycling share of recycling center material. We multiply that number by the coefficients in Table 11.

For recycling centers, the marginal effects of CRV and number of recycling centers is

Table 12: Marginal Effects of CRV and the Number of Recycling Centers
Sources: CalRecycle Data received July 2017

	Aluminum	Glass	PET	HDPE
CRV	2.027	0.6884	1.266	0.8478
LVRC	0.011	0.0255	0.051	0.0219

The marginal effect of CRV is the change in the percent recycled for a 1 cent increase in the CRV. For concreteness, a 1 cent increase in the CRV would increase the share of aluminum in recycling center material by 2 percent (e.g. from 90 to 92 percent) while it would only increase the share of glass recycled in recycling center material by 0.69 percent, less than one percent. These numbers show that the return of aluminum is much more sensitive to CRV than are the other materials.

While an increase in CRV does increase recycling center material, it does so by taking from both curbside and from the outside option, other means of disposal, including trash. For July 2015, recycling centers and curbside take up more than 100% of sales for aluminum. The logical conclusion is that an increase in CRV would lead to an increase in out of state imports or redirection from curbside to recycling centers.

For glass curbside is about 15% of sales. For the year 2016 the recycling rate was 72%, meaning that the outside option was 28%. The econometric model predicts that an increase in recycling centers will come at the expense of curbside and the outside option in proportion to their shares. That is that 35% of the increase in recycling centers comes from decreased curbside while 65% comes from decreasing the outside option. The outside option is what includes litter and trash. For PET curbside was about 6%. The

2016 recycling rate was 76%, so 24% is the outside option. Therefore 20% of the increase in door trade comes from curbside and 80% from the outside option.

Raising the CRV for PET and glass by 3 cents is financially feasible and results in a modest increase in recycling share. A three-cent increase in CRV leads to 2.1% increase in glass recycling of which 2/3 comes from the outside option. For 2016 this change the average rate for the year from 72% to 73.4%. It increases the contribution of unrecycled glass to the state fund balance by 52%.   PET is recycled at a year average rate of 76% for 2016. A three-cent increase in the CRV should bring in 3 more percent, raising it to 79%. The state fund contribution from unredeemed PET increases by 39%.

These marginal numbers come from an econometric model. The AmeriSpeak survey also asked about how many more people would recycle if the CRV were changed, though it did not do so by material. As noted earlier in the report, people disposing of containers in the trash state an increase to 7 cents lead to 11% saying they would redeem and an increase to 10 cents lead to 35% saying they would redeem. Of people who said that they were currently using curbside bins to recycle their beverage containers, an increase in the CRV to 15 cents was necessary before more than half would start taking containers to a recycling center, as well. At a CRV of 7 cents, 34% said they would redeem and at a CRV of 10 cents 41% said they would redeem. For instance, the 2016 PET non-recycled share was 24 percent. The recycled share would go from 76 to 78 with a 7 cent CRV. However, an increase of CRV to 7 cents would also lead to a 34% change from curbside to recycling centers. The survey respondents who use curbside were much more responsive to a potential increase in CRV than the people who threw out their containers.

A modest change in the number of recycling centers, say the addition of 100 centers state-wide, is predicted to bring in a few more percent of each material. PET is the most sensitive to number of centers; one hundred more centers is predicted to bring in 5% more PET in recycling center material at the expense of 1% in curbside for a net increase of 4%. For glass the increase, net of reductions in curbside, is 1.3%. For aluminum the net increase is less than 1%.

The effect of increasing curbside is shown in the table below.

Table 13: Effect of Increasing Curbside
Sources: CalRecycle Data received July 2017

	Aluminum	Glass	PET	HDPE
LVCS	0.00288	0.0325	0.0163	0.0360

Increasing curbside opportunities is not expected to bring in significantly more material in curbside. The table gives how much curbside would increase, but it would do so at the expense of the outside option and recycling center material. Since recycling centers are a very large component of total sales and the tabled marginal value is .003, one hundred new programs would increase aluminum recycling by less than 0.3 percent. For glass, 40% of curbside would come from the outside option and the recycling rate would increase 1.3% for a hundred new centers. For PET, only 20% of an increase in curbside comes from the outside option, so only 0.3% would be a net increase in recycling.

Simulations of Handling Fee Centers and CRV Changes on Disposal Choices

In this section, we run simulations to explore what happens to recycling if handling fee centers are no longer in operation or if there is an increase in the CRV to ten cents for all containers. These simulations are based on the AmeriSpeak survey of California residents and their beverage disposal habits conducted by NORC, explained in detail in the first section ("Recycling Center Convenience"). During the survey, we collected information about the beverage containers purchased by the household in the previous week, as well as the disposal methods chosen for each of those containers. One of the primary goals of the survey is to better understand which attributes of various disposal methods California residents value. This allows us to evaluate how changes in the CRV impact disposal method choices, and whether or not a closure of handling fee centers will impact recycling in California. We investigate whether residents value handling fee centers more than processing fee centers, and whether or not the closure of handling fee centers disproportionately impacts certain demographic or socioeconomic groups. In so doing, we hope to provide policy makers with important information on the efficacy of current recycling methods as well a path for recycling in the future.

Summary Statistics and Regression Model

Table 14 provides estimates of the reported volume of containers that enter each disposal method, based on the total number of containers purchased by our respondents over the previous week. The reported percentages are difficult to compare to the administrative volume data, which reports a much lower rate for curbside disposal, and a lower rate for recycling altogether. There are a few plausible explanations for the discrepancy. One is that many of the containers reported to be

thrown into curbside bins by our surveyed consumers may be collected by others to take to a recycling center. Another is that consumers may be over-reporting the number of containers recycled due to a possible inability to remember cold case purchases and their disposal (which generally occur outside of the home).

Table 14: Reported disposal methods for containers purchased over the previous week: Returned to a recycling center (RC), saved to return to a recycling center, used curbside, recycled in a bin outside of the home, threw into the trash, or used some other method (such as giving containers to a neighbor).
Source: AmeriSpeak Survey conducted June/July 2017

	RC	Saved for RC	Curbside	Other Recycling	Trash	Other
No. of Containers	8530	9142	6071	882	1372	2027
Percent of Total Containers	29.0%	31.1%	20.6%	3.0%	4.7%	6.9%

We run a flexible choice regression model to better understand the consumer preferences with respect to their disposal options. The choice of a random coefficients mixed logit model allows choices of disposal methods to vary across individuals, conditional on factors that lead to the use of recycling centers (rural residency, income, race, and age) as well as individual preferences. Table 15 displays the results of the model, where attributes of the disposal choices include the distance to the nearest recycling center, whether or not a recycling center receives a handling fee, and the CRV. The results show the average value across all consumers of the distance to a center, of handling fee centers compared to processing fee centers, and the CRV. In addition, we account for deviations from the average based on demographic characteristics, including income, race, age, education, and living in a rural location. Finally, we account for individual preferences.

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Table 15: Results of the Random Coefficient Mixed Logit model
Source: AmeriSpeak Survey conducted June/July 2017

	Choice of disposal method
Mean	
Distance	-0.069***
	(0.026)
CRV	6.637**
	(2.939)
Handling Fee Center	-0.244*
	(0.139)
Income*CRV	-0.088
	(0.033)
White*CRV	-1.639
	(1.006)
Age*CRV	0.188
	(2.888)
Education*CRV	-0.652
	(0.291)
Rural*CRV	3.177
	(1.962)
Observations	18055
Log Likelihood	-1792.311
AIC	3604.622
Note: *p<0.1; **p<0.05; ***p<0.01;	

The results imply that an increase in the distance to a recycling center by 1 km would lead to a 6.9% reduction in the probability that a person would choose to go to a

recycling center. There is no premium on handling fee centers. We find that if two centers are the same distance away, a household would be 24% more likely to choose the non-handling fee center. Handling fee centers are less likely to pay in cash, have shorter operating hours, and are limited in capacity and space, which may help explain the negative coefficient (as shown in Figure 1). We also see that higher educational attainment reduces the likelihood of using recycling centers as a disposal option. Other demographic factors, such as income, race, and living in a rural location do not have significant impacts on disposal choice.

Simulations and Impacts to Consumers

Next, we evaluate the change in consumer choices with respect to a closure of handling fee centers. We simulate a random closure of 1/3, 2/3 and all of the handling centers in operation in 2017. On average, the remaining centers will be farther away, but also more likely to pay in cash or operate at convenient hours. Table 16 shows how the average distance to a consumer's nearest recycling center changes if no handling fee centers remain in operation. Also shown are the differences for rural consumers, who see the greatest increase in distance to a recycling center.

Table 16: Average distance to the nearest recycling center (mi), with and without handling fee centers
*Source: AmeriSpeak Survey conducted June/July 2017 and Google Maps API*

	All RC Centers	No Handling Fee Centers
All Consumers	2.46 mi	3.98 mi
Rural Consumers	7.21 mi	16.11 mi

It's important to note that while there is nothing inherently different about rural consumers' preferences on disposal choices, rural consumers are generally further away from recycling centers. This means that rural consumers are less likely to use recycling centers, and an increase in the distance to recycling centers would lead to a further reduction in recycling center use. As shown in Table 16, if handling centers are no longer in operation, the distance to recycling centers would disproportionately increase for rural consumers, limiting their ability to find recycling centers within a reasonable distance.

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Figure 17 depicts the estimated and simulated choice probabilities under these scenarios. The top left panel of Figure 17 shows the predicted probabilities of the choices at baseline, with all existing handling fee centers. In the other extreme, on the bottom right panel, we see that after the removal of all handling fee centers from the set, no one takes containers to handling fee centers, and the predicted probabilities for recycling containers via curbside, trash, or processing fee centers increase. The magnitude of the change in the predicted probabilities for disposal through curbside and trash is much smaller than the change in probability of recycling at a processing fee facility. In addition, the probability of waiting to recycle at a processing fee facility (therefore going less frequently) increases as the number of handling fee centers decreases, suggesting that the longer distance to a recycling center reduces the number of trips a household would take.

Estimated and Simulated Choice Probabilities
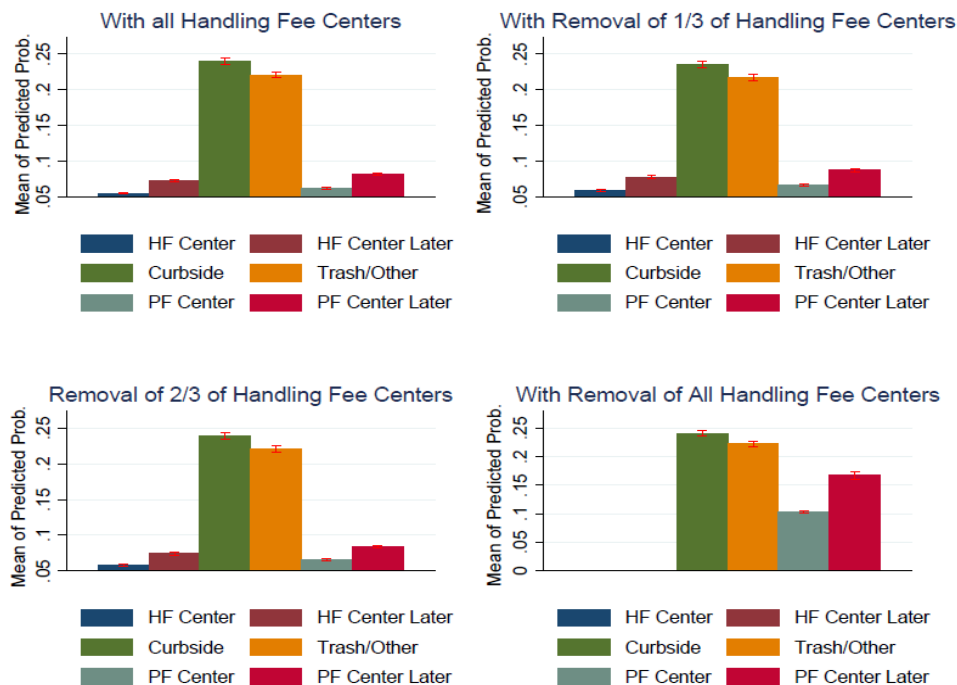
Based on Mixed Logit Choice Specification for 6 alternatives.
HF Center: Took containers to a handling fee center; HF Center Later: Saved containers to take to a handling fee center
PF Center: Took containers to a processing fee center; PF Center Later: Saved containers to take to a processing fee center

Figure 17: Simulated disposal choices made with all handling fee centers currently in

operation, and with the random removal of 1/3, 2/3, and all of the handling fee centers currently in operation.

In addition, we simulate the choices made with an increase in the CRV to ten cents for all containers. As expected, we find that recycling at recycling centers (both processing and handling fee centers) increases substantially, and that there is a significant reduction in curbside recycling and throwing beverage containers in the trash. The consumers most affected by the policy changes are the consumers who change their behavior, since a CRV redemption means that a consumer is only getting back what they paid in the original tax. The people who benefit from the increase in the CRV are the marginal consumers who were on the fence about going to a recycling center or not (white, higher income consumers). With an increase in the CRV to ten cents, it is more likely that going to a recycling center will be worth their time and effort.

As a takeaway, we find that a closure of handling centers across California would not have a major impact on the welfare of California residents. The handling fee centers were put in place in order to best serve all of California residents, such that no one was burdened by the scope of the tax. However, our analysis shows that people who would have gone to a handling fee center will continue to go to processing fee recycling centers, just at a lower frequency than they were going previously. This suggests that current CalRecycle policy may be better for the general public, and that the continual closure of handling fee centers may not significantly negatively impact recycling opportunities for consumers.

With respect to an increase in the CRV, we find that in general, the increase would encourage more recycling at recycling centers. Any positive benefits to consumers from an increase in the CRV are accrued by the consumers that were on the fence between recycling their containers using curbside or taking their containers to a recycling center and would now choose a recycling center. With an increase in the CRV, this would reduce the number of containers entering the curbside and trash streams, which would lower the revenue obtained by Cal Recycle for unredeemed containers but would also lower the environmental costs. If environmental costs were sufficiently high, this policy change would increase total welfare.

Recommendations

1. We recommend that the definition of convenient recycling be: recycling at centers that are nearby, open convenient hours, and have short lines.

2. We do not recommend taking any special action to save the smaller handling fee centers. These centers do not generally have convenient hours. They have a high cost to the system to maintain. If a consumer is the same distance away from a handling fee center and a processing fee center, on average they prefer the processing fee center. Consumers state that they are willing to travel a little further than they do today, so the small, if any increase in travel does not argue for saving them. Only 17% of consumers believe that there is a special value to have them collocated with supermarkets. Yet rural consumers may find handling fee centers to be useful, in that an elimination of handling fee centers leads to a disproportionate increase in the distance to a recycling center, making recycling more difficult.

3. We do recommend considering easing the convenience zone requirement. In practice this is done through the waiver process. The waiver process, requires any of: "Ease of access to redemption center by consumers, reasonable distance to next closest recycling center, consumers in area predominantly use curbside program for recycling, and recycling centers in the area fail to meet a sufficient volume for economic viability." A natural consequence of decreasing scrap values is that the small centers will be uneconomic. In granting exemptions, CalRecycle should be mindful of the local, not statewide, patterns of car use. At the current density of recycling centers, loosing additional centers has very little effect on overall collection.

4. We do not recommend increasing the payment to handling centers, however for each penny of additional handling fee they are paid, there would be 148 new handling fee centers. Neither a lump sum bonus nor an extra payment for the first tranche of containers should be used to prop up these centers.

5. Lowering the cap on material returnable in a day will not make a difference to most diverters. They deliver well below the cap. Other recyclers, however, deliver more material per load less frequently and would be affected by a large change in the cap. Lowering the cap would make recycling less convenient as it would require more trips.

6. Should scrap values continue to trend lower or if the fund should need to correct a structural deficit, there are two options to raise money for the Fund. Raising the CRV on glass, PET and HDPE will only modestly increase recycling but will provide more unredeemed container revenue to the Fund. Raising the CRV on aluminum is problematic since this material is already returned at a high rate. A higher CRV would also further incentivize illegally imported aluminum. The other potential source of funds is to return to the principle that beverage manufacturers are responsible for the

processing fee. Having beverage manufacturers pay does not incentivize further returns or illegal importation.

7. If increased convenience is required, the requirement for open hours for handling fee centers should be changed to better match shopping hours. This is likely to increase their collection of material and consumer convenience. However, one must recognize that a handling fee center could now choose to have more open hours. The fact that they do not have these extended hours means that they or their host supermarkets do not consider this desirable or profitable.