Estimating Spillover in Upstream Lighting Programs: Hard Data for an Elusive Number<br>Louise Song, The Cadmus Group, Inc., Boulder, CO<br>Joshua Keeling, The Cadmus Group, Inc., Portland, OR<br>Eric Rambo, The Cadmus Group, Inc., Madison, WI<br>Andrew Carollo, The Cadmus Group, Inc., Portland, OR<br>Jason Christianson, The Cadmus Group, Inc., Portland, OR


#### Abstract

This paper describes Cadmus' approach to evaluating spillover for an upstream lighting program in a Mid-Atlantic state. Our research combines two empirical approaches.

We used detailed sales tracking data provided by the implementer to estimate a demand curve for program compact fluorescent lamps (CFLs). This price response model predicts purchases at different price points, providing an estimate of increased sales due to program markdowns. To estimate freeridership we subtracted the calculated total reduction in sales from the sales that would have occurred without the program. This method is reported elsewhere.

To account for spillover, we estimated the impact of promotional pricing on sales, using the same model. The difference in sales between this hypothetical price scenario and the prices customers actually encountered represents net sales attributable to the program, or the program's lift. The lift comprises two components: (1) incentives provided by the program and (2) additional price effects related to retailer discounts. These additional price effects can be viewed as program spillover.

We combined the price response model with a careful shelf study of prices, where we observed the price of program and non-program lamps in both participating and non-participating stores. We observed that the actual price paid for program CFLs in participating stores is reduced more than the amount of the program buydown, a spillover effect of the program. This paper describes our research and the case for treating additional price effects as program spillover.


## Program-Induced Sales Lift

The effect of an upstream program on the market for CFLs is to "lift" sales by decreasing the price of the measure; that is, the additional sales that would not have occurred at the higher price. Sales that would have occurred without the incentive must be netted out of the program effect. The ratio of program-induced sales to total program sales is the net-to-gross (NTG) ratio. This relationship is illustrated in Figure 1.


Figure 1. Price Response and Net Program Effect
To apply this price-response approach to determine net program effects we need to estimate a demand curve that specifies the relationship between price and quantity purchased. From our work evaluating a lighting program in a Mid-Atlantic state, we had the data needed to estimate such a curve.

## Freeridership vs. Spillover

The net program effect is composed of two parts: (1) freeridership, which is netted out of the program effect and (2) spillover, which is added back into the program effect. Figure 1 might imply that the program effect is due entirely to the incentive provided directly by the program. If this were the case, there would be no spillover from the program. If the price effect of the program can be shown to be greater than the amount of the program incentive, this would be a form of spillover from the program.

Figure 2 shows a hypothetical scenario where both freeridership and spillover affect the net program impacts.


Figure 2. Price Response Showing Spillover Price Effects
In Figure 2, the direct effect of the program on price, through buydown incentives paid to retailers, moves the price from the point marked "b" to the point marked "c." This shifts the quantity of lamps demanded from the point marked " $y$ " to the point marked " $z$." The price of lamps without the program is not at point "b" in our hypothetical scenario, however, because the program has had an indirect effect of lowering prices more than the amount of the incentive. This is discussed below as "adjusted additional price impact".

The full program effect on price is from "a" to "c," with the full effect on quantity from "x" to " $z$." The effect from " $x$ " to " $y$ " is the program spillover.

We have empirical evidence from two recent studies of residential lighting in this jurisdiction that the additional price reduction represented in Figure 2 is real. We know from our price response modeling that retailers combine program incentives with additional price reductions-"sweeteners"-to further discount products. And we know from our shelf study of prices at program and non-program stores that prices at program stores are generally lower than prices for the same or equivalent lamps at non-program stores.

## Price Response Modeling

To estimate the program effect for efficient lighting products in a Mid-Atlantic state, Cadmus estimated its elasticity of demand for two utilities operating in the state. We used tracking data collected by the program implementer. For each unique combination of retailer, model number, and incentive level, the tracking data contained these data fields, which were relevant to our analysis:

- Original retail price
- Incentive provided by the utilities
- Discounted retail price, i.e. price with incentive included
- Number of lamps per package
- Rated wattage
- Rated lifetime in hours
- Model designation (specialty, light-emitting diode [LED], fixture, standard)
- Program month in which the product was sold


## Methodology

Cadmus modeled the sales tracking data as a cross-section of program package quantities over time. The model predicts the quantities purchased of each package type as a function of price as well as of other factors that might influence purchase decision-making, such as program promotional activity. Of total sales of all bulbs, we found that $57 \%$ of the incented bulbs of one utility and $39 \%$ of the other utility varied their prices over the evaluation period.

Because we knew the price of all lamps both with and without incentives, price and demand variations during the study period could be used to estimate the market response to program discounts. We tested the model for both all lamps and only bulbs with varying incentives. Both scenarios yielded similar results.

Cadmus modeled product sales over time as a function of price, incentive, number of promotional events, and other relevant variables described below. (This model assumes that lamp sales are a function of lamp characteristics, seasonal trends, and price.) We tested a variety of specifications to ascertain the impact of price on the demand for lamps. ${ }^{1}$

We estimated the basic equation for the revealed-preference model as follows (for lamp model i, in period t ):
$\ln \left(Q_{i t}\right)=\beta_{1}+\beta_{2} \ln \left(P_{i t}\right)+\sum_{\theta}\left(\beta_{\theta}\left[\right.\right.$ Retailer $\left.\left._{\theta, \mathrm{i}} * P_{i t}\right]\right)+\sum_{\pi}\left(\beta_{\pi}\right.$ Model $\left._{\pi, \mathrm{i}}\right)+\sum_{\delta}\left(\beta_{\delta}\right.$ Month $\left._{\delta, t}\right)+\varepsilon_{i}+\gamma_{t}$

Where:

| $\ln$ | $=$ | natural log |
| :---: | :---: | :---: |
| Q | $=$ | quantity of lamps sold during the month |
| P | = | average retail price (after incentives) in that month |
| Retailer | = | dummy variable equaling 1 for each retailer; 0 otherwise |
| Model | $=$ | dummy variable equaling 1 for each unique retailer and model number; 0 otherwise |
| Month | $=$ | dummy variable equaling 1 in a given month; 0 otherwise |
| $\varepsilon_{i}$ | = | cross-sectional random error term |
| $\gamma_{t}$ | $=$ | time series random error term |

We tested these other possible candidates for explanatory (independent) variables:

- Unit type (standard, LED, specialty)
- Package size

The $\beta_{2}$ and $\beta_{\theta}$ coefficients represent the price elasticities of demand for program lighting measures, that is, the rate at which sales change as a function of price changes. There are two values because the model specifies a logarithmic relationship that is global across the market and a relationship that is specific to each retailer. Using these estimates, we predicted sales with and without the program.

[^0]Cadmus used the model coefficients to predict sales under two conditions: (1) had prices been at their original retail price and (2) had no promotional events taken place. The sum of the predicted sales without the program (at the original retail price) for each lamp model number multiplied by its gross annual energy savings produces the total predicted energy savings without the program. Likewise, the sum of the predicted sales with the program (at markdown price) for each lamp model number multiplied by its gross annual energy savings produces the total predicted energy savings with the program. That is:

Savings without Program

$$
=\sum \text { Gross Annual Unit Savings } s_{i} * \text { Predicted Sales at Original Retail Price }{ }_{i}
$$

Savings with Program

$$
=\sum \text { Gross Annual Unit Savings } i_{i} * \text { Predicted Sales at Markdown Price }{ }_{i}
$$

The difference in sales (weighted by gross annual energy savings) between the hypothetical scenario and what actually occurred provides net sales attributable to the program. The ratio of these sales to the total program sales is equal to freeridership, as shown in the following equation.

$$
\mathrm{NTG}=\frac{\text { Savings with Program }- \text { Savings without Program }}{\text { Savings with Program }}
$$

## Findings

Cadmus found program-wide net effects to be within values expected for a mature upstream lighting program. As expected, net impacts increased as price was further reduced relative to the unincented price. For instance, the net program effect for LEDs was estimated to be $22 \%$ of the gross impact; the net program effect for standard CFLs was estimated to be $59 \%$. The blended NTG ratio across all lamp types was estimated to be $50 \%$.
provides values for standard and specialty CFLs and LEDs.
Table 1. Program Effect by Bulb Type

| Type | Original <br> Retail Price <br> per Bulb | Average Price <br> Reduction per <br> Bulb | Price <br> Reduction as <br> Percent of <br> Original Price | Net Program <br> Effect (NTG) |
| :--- | :---: | :---: | :---: | :---: |
| LEDs | $\$ 34.30$ | $\$ 9.69$ | $28 \%$ | $22 \%$ |
| Reflector | $\$ 4.70$ | $\$ 1.82$ | $39 \%$ | $39 \%$ |
| Specialty | $\$ 5.23$ | $\$ 1.73$ | $33 \%$ | $33 \%$ |
| Standard | $\$ 2.03$ | $\$ 1.23$ | $61 \%$ | $59 \%$ |

Source: Cadmus analysis.

## Freeridership vs. Spillover

Using information about program buydowns and retailer "sweeteners," we can decompose the net impact into freerider and spillover components. Across all lamp types, the price response model estimated a NTG value of 0.50 . Table 2 shows that the estimated NTG value can be decomposed into two parts based on the value of program incentives and accompanying retailer incentives. The spillover in this case is small, that is, less than $1 \%$. We believe, however, that it is only part of the spillover due to price effects related to residential programs.

Table 2. Freeridership and Spillover Components of NTG

| Source | Program Attribution |
| :--- | ---: |
| Program Incentives | 0.496 |
| Retailer Incentives | 0.004 |
| NTG | $\mathbf{0 . 5 0 0}$ |

## In-Store Pricing Study

The strength of the price response model for estimating NTG is that it develops an estimate only on the basis of actual data related to program lamps. No additional information is needed to estimate freeridership.

For spillover, however, any price-response model that looks only at program lamps will miss the effect of the program on non-program lamps. In a market where programs are systematically reducing the price for some lamps, we would expect that both manufactures and retailers that are not participating in the program would feel the downward pressure on prices-in the form of reduced demand as some customers sought out lower-priced program lamps-and they would tend to respond by also lowering prices. This is an additional effect of a residential lighting program on the market for lamps.

The size of this effect, however, is a difficult number to obtain. Our in-store pricing study sheds light on these program price effects on non-program lamps.

In October 2012, the Cadmus team collected data about energy-efficient lamps stocked in 20 stores across the same Mid-Atlantic state; 12 of these stores participated in the statewide Residential Lighting Program. During the site visit, we observed trends in the market related to stocking practices, manufacturers, differences between lamps stocked by participating stores and nonparticipating stores, differences between program and non-program lamps, and prices. Moreover, we verified the presence and prices of program lamps compared to a list of program-qualified lamps provided by the utilities.

## Data Collection

During each store visit, the Cadmus team documented every energy-efficient lamp available for purchase (both program and non-program lamps) for 967 individual lamps. For each individual lamp, the team recorded key characteristics, including manufacturer, model number, style, wattage, incandescent wattage equivalent, number of lamps per pack, base type, shape, dimmability, three-way functionality, ENERGY STAR ${ }^{\circledR}$ branding, the price as listed and any non-program discounts, lumens, color, kelvin, and lifetime.

To improve the data collection ease and efficiency, the evaluation team developed an iPad application for the data collection team to use during the in-store lighting study. We determined which stocked lamps were program lamps by the way they were marked on the shelves.

Using utility-provided sales data, the team chose the six retailers that sell the most lamps statewide across three merchandising channels: home improvement, warehouse, and mass merchandising. We selected two participating stores per retailer, one each in a low- and high-income area. ${ }^{2}$

Cadmus originally planned to draw the nonparticipating retailer sample from similar retailers. But because so many retailers are involved with the program, we had a limited sample from which to draw these nonparticipants. The team selected four retailers that also sell efficient lighting products: two mass merchandising retailers, one warehouse retailer, and a hardware store. Again, the team visited two stores from each retailer, one from a low-income area and one from a high-income area.

## Pricing Trends

The evaluation team observed several pricing trends among program and non-program lamps, as well as among participating and nonparticipating stores:

- Trend A: Program lamps were less expensive than non-program lamps at participating stores
- Trend B: Program lamps were more expensive than non-program lamps at nonparticipating stores
- Trend C: Program lamps were less expensive at program stores than at nonparticipating stores
- Trend D: Non-program lamps were less expensive at program stores than at nonparticipating stores

To help illustrate this pattern, in Table 3 we show the general order of lamp prices observed at participating and nonparticipating stores. The order is from 1 being least expensive to 4 being the most expensive. Thus, a program lamp at a participating store is the cheapest, but the same type of lamp at a non-participating store is the most expensive.

Table 3. The Order of Prices for Program and Non-program Lamps in Participating and Nonparticipating Stores

|  | Participating <br> Store | Nonparticipating <br> Store |
| :--- | :---: | :---: |
| Program Lamp | 1 | 4 |
| Non-program Lamp | 2 | 3 |

These trends occurred for all lamp types and mostly remained consistent when controlling for potential differences in distribution channels, quality, pack size, wattage, and light color. ${ }^{3}$ There were too few LEDs in the sample, however, to apply these additional controls so all LEDs are included in a single category. Table 4 shows the consistency of the four trends noted above across select lamp categories. We have included only categories where there was a significant quantity of lamps on which to base a comparison. Only standard CFLs at mass merchandising stores contradict Trend A; in this case, program lamps were more expensive than non-program lamps at participating stores.

[^1]Table 4. Price Trends by Lamp Category

| Category | Participant Status | Lamp Status | Frequency | Average Price | Price Order |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Standard CFLs | Nonparticipant | Program | 25 | \$9.04 | 4 |
|  |  | Non-program | 149 | \$6.07 | 3 |
|  | Participant | Non-program | 38 | \$4.09 | 2 |
|  |  | Program | 143 | \$2.21 | 1 |
| Standard CFLs at Mass Merchandising Stores | Nonparticipant | Program | 15 | \$9.14 | 4 |
|  |  | Non-program | 62 | \$5.87 | 3 |
|  | Participant | Non-program | 15 | \$2.21 | 1 |
|  |  | Program | 50 | \$2.73 | 2 |
| Standard CFLs in packs of 1,2 , or 3 | Nonparticipant | Program | 24 | \$9.20 | 4 |
|  |  | Non-program | 121 | \$6.64 | 3 |
|  | Participant | Non-program | 25 | \$5.25 | 2 |
|  |  | Program | 59 | \$3.79 | 1 |
| Specialty CFLs | Nonparticipant | Program | 20 | \$10.89 | 4 |
|  |  | Non-program | 115 | \$9.85 | 3 |
|  | Participant | Non-program | 165 | \$7.35 | 2 |
|  |  | Program | 135 | \$3.99 | 1 |
| Specialty CFLs at Mass Merchandising Stores | Nonparticipant | Program | 13 | \$8.98 | 4 |
|  |  | Non-program | 45 | \$8.64 | 3 |
|  | Participant | Non-program | 57 | \$5.96 | 2 |
|  |  | Program | 53 | \$3.53 | 1 |
| Specialty CFLs in packs of 1, 2 or 3 | Nonparticipant | Program | 20 | \$10.89 | 4 |
|  |  | Non-program | 115 | \$9.85 | 3 |
|  | Participant | Non-program | 160 | \$7.48 | 2 |
|  |  | Program | 123 | \$4.22 | 1 |

Source: Cadmus analysis.

## Additional Program Impact

The contrast between program lamps at participating and non-participating stores could be explained by the incentive paid by the program to reduce the price at participating stores. However, the price reduction is substantially greater than the value of the incentives. As shown in Table 5, the amount of the program incentive is systematically less than the difference between prices at participating and nonparticipating stores.

Table 5. Participating and Nonparticipating Store Prices for Program Lamps and Average Incentive Amount

| Lamp Category | Average Price <br> Nonparticipating <br> Stores | Average Price <br> Participating <br> Stores | Difference in <br> Average <br> Prices | Average <br> Program <br> Incentive |
| :--- | :---: | :---: | :---: | :---: |
| All Standard CFLs | $\$ 9.04$ | $\$ 2.21$ | $\$ 6.83$ | $\$ 1.24$ |
| Standard CFLs in packs of <br> 1,2, or 3 | $\$ 9.20$ | $\$ 3.79$ | $\$ 5.41$ | $\$ 1.23$ |
| Standard CFLs at Mass <br> Merchandising Stores | $\$ 9.14$ | $\$ 2.73$ | $\$ 6.41$ | $\$ 4.55$ |
| All Specialty CFLs | $\$ 10.89$ | $\$ 3.99$ | $\$ 6.90$ | $\$ 2.02$ |
| Specialty CFLs in packs of <br> 1,2, or 3 | $\$ 10.89$ | $\$ 4.22$ | $\$ 6.67$ | $\$ 2.00$ |
| Specialty CFLs at Mass <br> Merchandising Stores | $\$ 8.98$ | $\$ 3.53$ | $\$ 5.45$ | $\$ 1.24$ |

Source: Cadmus analysis.
Although we made an effort to match participating stores with similar nonparticipating stores, it is likely that, given our small sample, there are systematic differences between the two groups that could partially account for these large differences in price. In an effort to account for these unknown differences, we made an adjustment to the average price of program lamps at nonparticipating stores. We calculated the ratio of the prices of non-program lamps at participating and nonparticipating stores and applied this ratio to the price of program lamps at nonparticipating stores. The logic is that the difference in prices of non-program lamps is due not to the program effect but to differences between the stores. The adjustment factors out this difference. The adjustment is as follows:

> Adjusted PPLnonpart = PNPLpart / PNPLnonpart * PPLnonpart

Where:
PPL $_{\text {nonpart }}=$ Price of program lamps at nonparticipating stores
PNPL $_{\text {part }}=$ Average price of non-program lamps at participating stores
PNPL $_{\text {nonpart }}=$ Average price of non-program lamps at non-participating stores

Even with this adjustment, the average price of program lamps at nonparticipating stores was greater than the average price of program lamps at participating stores in most instances. Figure 3 shows the components of prices for several categories of lamp, after adjusting for overall differences in store prices. For each ategory, the full length of the bar is the average price at non-participating stores. The dark blue section of the bar is the price at participating stores. The medium blue section represents the average incentive amount. The remainde is the additional price effect, unattributable to incentives.


Figure 3. Components of Price Comparing Participating and Non-Participating Stores
Table 6 shows the same results in table form. If we discount the difference between participating and nonparticipating stores, using the figures for adjusted additional price effect, we can see that the remainder for most categories is at least as large as the incentive itself. and that the category of all standard CFLs is more than twice the value of the incentive. The exception is for standard CFLs at mass merchandising stores, where the adjusted additional price effect is only about $19 \%$ as large as the average incentive (that is, $\$ 0.85 / \$ 4.55=0.19$ ). Even this suggests a significantly larger additional effect on program lamps than was caught in the price response modeling.

Table 6. Additional Program Price Effects

|  | Adjusted <br> Average <br> Price Non- <br> participating <br> Stores | Average Price <br> Participating <br> Stores | Difference in <br> Average <br> Prices | Average <br> Program <br> Incentive | Adjusted <br> Additional <br> Price Effect |
| :--- | :---: | :---: | :---: | :---: | :---: |
| All Standard CFLs | $\$ 6.09$ | $\$ 2.21$ | $\$ 3.88$ | $\$ 1.24$ | $\$ 2.64$ |
| Standard CFLs in <br> packs of 1, 2, or 3 | $\$ 7.27$ | $\$ 3.79$ | $\$ 3.48$ | $\$ 1.23$ | $\$ 2.25$ |
| Standard CFLs at <br> Mass Merchandising <br> Stores | $\$ 7.61$ | $\$ 2.21$ | $\$ 5.40$ | $\$ 4.55$ | $\$ 0.85$ |
| All Specialty CFLs | $\$ 8.13$ | $\$ 3.99$ | $\$ 4.14$ | $\$ 2.02$ | $\$ 2.12$ |
| Specialty CFLs in <br> packs of 1, 2, or 3 | $\$ 8.27$ | $\$ 4.22$ | $\$ 4.05$ | $\$ 2.00$ | $\$ 2.05$ |
| Specialty CFLs at <br> Mass Merchandising <br> Stores | $\$ 6.19$ | $\$ 3.53$ | $\$ 2.66$ | $\$ 1.24$ | $\$ 1.42$ |

## Conclusions

Our view is that the adjusted additional price effect is a form of spillover. That is, without the program, the average price of standard CFLs would not have been the observed price plus the incentive but would have been the observed price plus the incentive, plus the additional price effects. In our price response model, these additional effects amounted to only $1 \%$ (see Table 2) of the total effect because they included only an additional amount of incentive provided by the retailer, that is, the sweetener. What our shelf study data suggest is that spillover also occurs from the additional price effects we have observed.

The price response model shows the logic and method by which we estimate NTG and apportion part of the effect to spillover. Our shelf study, however, makes it clear that using implementer price information captures only part of program spillover. The price of program CFLs at participating stores is lower than the price of the same CFLs at non-participating stores; this difference is greater than could be accounted for by the value of retail incentives added onto program incentives, which accounts for less than $1 \%$ of program attribution.

We cannot claim, based on our shelf study, that all of the additional price effects are attributable to the program. In part, our study was not large enough to rule out alternative explanations for price differences. Our effort to control for store differences, while it was the best we could do with the information available, is not robust enough to ensure factors other than program participation are not affecting the price comparison. A larger study would allow more careful controls and provide a more accurate estimate of price effects over and above program incentives.

Thus, we capture one small portion of spillover using the most unequivocal data we have: data gathered by the program implementer. Further, we make an effort to capture additional spillover effects by comparing CFL prices on program lamps in participating and non-participating stores.

Two other price effects can be predicted on the basis of microeconomic theory. First, program incentives would be expected to put downward pressure on the price of non-program CFLs at participating stores. Second, prices of CFLs at nonparticipating stores would also feel downward price pressure from competitor store prices. These are both direct program effects that are not captured by any NTG analysis of upstream lighting programs that we are aware of. Our own data show that non-program CFLs are less expensive at participating stores than at nonparticipating stores. We used this difference, however, to adjust for differences between stores that are unrelated to program participation, discounting the full difference of price in CFLs promoted by the program. It may be that some of this difference in the price of non-program CFLs is due to store differences, but another part of the difference amounts to an additional spillover effect. We are not close to estimating the size of these two additional program spillover effects but we do not think they are unknowable, given sufficiently detailed and accurate price information.


[^0]:    ${ }^{1}$ The focus of these diagnostics was to ensure that we included all explanatory variables and that no omitted variable or specification biases were present. Ensuring optimal model fit and minimizing multicollinearity were secondary goals of the modeling process.

[^1]:    ${ }^{2}$ Using 2008 through 2012 American Community Survey Data, the team determined income status by median household income and educational attainment (individuals over 25 years who have received a bachelor's degree).
    ${ }^{3}$ The team determined lamp quality by the lamps' lifetime across wattage bins, with the top $50 \%$ categorized as high quality and the bottom $50 \%$ categorized as low quality.

