How Much Is That CFL in the Window? I Do Hope It Is on Sale: Examining Price Differentials between CFL and Incandescent Light Bulbs

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Abstract

Market transformation programs often include incentives that serve to catalyze the adoption of energy efficient products. As market transformation takes place, one general indicator is that the price differential between the standard product and the energy-efficient product should decline due to the temporary market support of the incentives, technological advances, mass production, competition and other market forces. As price differentials decline, incentive levels can be reduced, and ultimately eliminated.

In the case of the residential lighting market, a key indicator of the state of market transformation is the price differential between a CFL and a comparable incandescent bulb. This study uses data from a survey of lighting product retailers conducted in Massachusetts at the beginning of 2006 to assess the differences in prices between CFL and comparable incandescent bulbs. Data were analyzed on two types of incandescent bulbs—standard and 3-way bulbs—and on five types of CFLs—standard CFLs and four specialty CFLs.

Results from this analysis provide several price indicators of the market transformation of the Massachusetts residential lighting market. In addition, this analysis can help program managers determine appropriate incentive levels for CFL light bulbs. While program managers often depend upon anecdotal or gut level estimates of appropriate incentive levels, this analysis can provide a more rational basis for setting incentive levels.

Introduction

This study uses data from a survey of lighting product retailers conducted in Massachusetts as part of the Market Progress and Evaluation Report (MPER) for the 2005 Massachusetts ENERGY STAR® Lighting Program. The Massachusetts ENERGY STAR Lighting Program is an ongoing effort to encourage the use of ENERGY STAR-qualified lighting among residential customers. For many years the Massachusetts Sponsors, both individually and collectively, have had active energy-efficient lighting programs that included markdowns/buydowns, catalog sales, direct installs, retail coupons, and consumer education. The Sponsors also work with other regional programs through the Northeast Energy Efficiency Partnerships (NEEP) to leverage program effectiveness by aggregating markets and coordinating consumer messaging. Additionally, all Sponsor lighting initiatives are coordinated with and designed to support the national ENERGY STAR program.

Since 2002, the Sponsors' Lighting Program has included three basic components:

- Negotiated Cooperative Promotions (NCP)
- The ENERGY STAR Lights catalog (and website)
- Instant rebate coupons

In 2005, 93% of the products distributed through the Massachusetts ENERGY STAR Lighting program came from the NCP component. NCPs represent the Sponsors' most extensive effort to support industry initiatives that promote ENERGY STAR-qualified lighting products. NCPs are agreements with manufacturers and their retail partners to discount selected ENERGY STAR-qualified bulbs and fixtures as well as provide other promotional support such as advertising, point-of-purchase (POP) materials, and consumer education activities. In 2005, the NCP program reduced product prices by an average of $1.85 per bulb (amounts ranged from $1 for single bulbs up to $8 for multi-packs). Prices for bulbs sold through the NCP program have in some cases been comparable to prices for incandescents, leading customers to purchase large quantities of CFLs. NCPs have been particularly successful in providing a large volume of products to the market, with over three million CFLs sold through the NCP program in 2005. Setting appropriate incentive levels is an important issue as CFL prices decline over time. For example, the import value[1] of a CFL has declined from $2.20 per CFL in 2004 to $1.51 per CFL in the first quarter of 2007. (Table 1)

Table 1: Annual U.S. Shipments of Screw-Based CFLs

Year	Shipments	Total Value	Value per CFL	% Change
2004	93,475,116	$205,939,403	$2.20	NA
2005	101,772,949	$203,807,858	$2.00	-9.1%
2006	184,686,594	$315,653,956	$1.71	-14.7%
2007 1stQ	76,939,726	$116,463,439	$1.51	-11.4%

Source: U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics

Program-related shipments of CFLs have increased dramatically since the Sponsors first began offering a joint efficient lighting program—from 158,000 in 1998 to 3.3 million in 2005, and lifetime savings resulting from the 2005 program year are estimated to be almost 950,000 MWh, as adjusted for hours of use, in-service rates, and free ridership, but not spillover. The cost per average MWh saved is estimated to be about $11, without taking spillover into account. Total sales of CFLs in Massachusetts in 2005—including program-supported sales—appeared to amount to nearly six million bulbs—about double the number sold through the program. The market share of CFLs relative to all bulbs is up to about 10.1% in Massachusetts in 2005 compared 2.8% in the U.S. as a whole.[2]

Methodology

This study uses data from a survey of lighting product retailers conducted in Massachusetts during the first quarter of 2006 to assess the differences in prices between CFLs and comparable incandescent bulbs. For the analysis we used data on 1,093 unique bulb models that were collected from a total of 37 retailers, including retailers participating in the NCP program, non-participating stores in participating chains, and non-participating retailers. Stores were sampled in order to best estimate CFL sales in

[1] Import values represent the customs value at the time the products are imported to the United States, but does not include import duties, freight, insurance, and other charges.

[2] *Market Progress and Evaluation Report (MPER) For the 2005 Massachusetts ENERGY STAR® Lighting Program* and *California Residential Efficiency Market Share Tracking: Lamps 2005*

Massachusetts.[3] Overall, we used data on two types of incandescent bulbs—standard and 3-way bulbs—and on standard CFLs and nine types of specialty CFL products, although four specialty types were ultimately included in the analysis (3-way bulb, flood bulb, A-bulb, and other specialty CFL bulb). For our analysis we corrected CFL bulb price for any program incentives. We should note that the CFL market has experienced some dynamic changes since the data were collected in the first quarter of 2006, including Wal-mart's goal to sell 100 million CFLs,[4] and proposals by state legislators in California and Connecticut to ban the sale of incandescent bulbs.[5,6] In addition, our data do not include other potentially useful CFL characteristics such as bulb life cycle and color temperature.

We conducted analyses to answer the following sets of questions:

1. What is the incremental cost of a CFL over an incandescent light bulb among medium screw-based bulbs, controlling for wattage and place of sale?
2. Among CFL bulbs alone:
   a. What is the incremental cost per lumen?
   b. What is the price difference between an ENERGY STAR CFL and a non-ENERGY STAR CFL, while controlling for lumens of light output, specialty features of CFL bulbs and major manufacturers of CFL bulbs?
   c. What it the price difference between a pin-based and screw-based CFL, while controlling for lumens of light output, specialty features of CFL bulbs and major manufacturers of CFL bulbs?
   d. What is the incremental cost for various specialty features?

Analysis and Discussion

Incremental Cost Analysis

To estimate the incremental cost of a CFL over an incandescent light bulb among medium screw-based bulbs we used logistic regression to predict the maximum likelihood of whether a bulb was a CFL or an incandescent based upon price per bulb, wattage and place of sale (a big box store such as Home Depot or Wal-Mart, or a grocery, drug store, or small hardware).[7] Logistic regression was used because of limitations in the data that violated the assumptions of multiple linear regression.[8]

[3] For more information on the store sampling procedures see Nexus Market Research, Inc., RLW Analytics, Inc., Shel Feldman Management Consulting, and Dorothy Conant. 2006. *Market Progress and Evaluation Report (MPER) For the 2005 Massachusetts ENERGY STAR® Lighting Program*

[4] See Fishman, Charles. 2006. "How Many Lightbulbs Does it Take to Change the World? One. And You're Looking at It.", *Fast Company*. September.

[5] See Yi, Matthew. 2007. "California Lawmaker Takes on Light Bulbs." *San Francisco Chronicle*, February 9, 2007.

[6] See Stannard, Ed. 2007. "State Lawmakers Have a Bright Idea." *New Haven Register*. February 1, 2007.

[7] Our logistic regression model also included an independent variable for three-way bulbs, but it was not a significant variable in the model. In addition, the analysis was limited to bulbs with a price of $11 or less and excluded incandescent bulbs over 150 Watts and less than 25 Watts as comparable CFLS for extremely high and low wattage incandescent bulbs are not readily available.

[8] Multiple linear regression analysis requires that several underlying assumptions about the data and the variables used in the analysis must be met. For this analysis, two major assumptions were not met. First, the residual terms from the analysis were highly correlated, violating the assumption that residual terms are not correlated. We believe that the autocorrelation was largely due to two factors. First, there were large numbers of incandescent bulbs with very similar prices at the same wattage, creating near duplicate data points. Attempts to remove bulbs with identical prices, wattage, and manufacturer did not resolve the problem of autocorrelation. Second, there were limited data on the specialty features of most incandescent bulbs (i.e.,

Logistic regression is an analytical technique that predicts a binomial outcome, in this case CFL bulb or incandescent bulb, with multiple independent variables that can be either continuous data or categorical data. With the results of our logistic regression model we can calculate probabilities of a bulb being classified as a CFL or incandescent (dependent variable), based upon a specified model of wattage, price and retailer type (independent variables). The result of our specified model is as follows:

$$\text{Logit}(\pi) = 6.97 - .438*(\text{Watts}) + .94*(\text{Price per bulb}) + 1.151*(\text{Place of sale})$$ [9]

Where π = the probability of a bulb being identified as a CFL, *Watts* is the wattage of the bulb, *Price per bulb* is the price of the bulb in dollars and *Place of sale* is 1 for a big box store and 0 for a non-big box store.[10] The model was highly significant, with an overall χ^2 value of 957.950 ($p < .001$), and the model correctly identified 97% of the bulbs in the data set ($n = 1,246$).

From this model we estimate that, taking into account incentives provided by the Sponsors, the incremental cost of a 25-watt CFL over a comparable 100 watt incandescent bulb is $4.39, and that a CFL costs $.97 less at a big box store than at a non-big box store. We should note, however, that our logistic regression analysis does not give estimates of bulb prices *per se*. Instead, it produces a probability that a given bulb is a CFL or an incandescent at a specified combination of wattage, price and place of purchase. According to the model, as price increases, the bulb is more likely to be identified as a CFL; conversely, as wattage increases, it is more likely to be identified as an incandescent bulb. As a result, the model is not as effective at estimating price differences at low and high wattages.

Our model is based on the assumption that CFL and incandescent bulbs are essentially interchangeable and that two of the primary factors that affect a consumer's choice between CFL and incandescent bulbs are wattage and price. Using data from the Department of Energy's Office of Energy Efficiency and Renewable Energy, Table 2 shows categories of wattage equivalents for CFL and incandescent bulbs, from which we have derived our price estimates for both CFL and incandescent bulbs from the corresponding wattages below:

Table 2: Comparable Wattage of CFL and Incandescent Bulbs

Incandescent Wattage	CFL Wattage
25	5
50	9
60	15
75	20
100	25
120	28
150	39

Source: http://www.eere.energy.gov/consumer/your_home/lighting_daylighting/index.cfm/mytopic=12060

flood light, reflector bulb, etc.), making it difficult for the multiple regression model to differentiate between bulbs of identical wattage but different prices. Other attempts to resolve the problem of autocorrelation led to violations of a second assumption of multiple linear regression, that independent (or predictor) variables should not be highly correlated to each other (i.e., multicollinearity).

[9] All independent variables in the model are significant at $p \leq .002$

[10] The following stores were classified as a big box store: BJs, Home Depot, Lowe's, Wal-Mart, and Sam's Club

To derive the price estimate of a CFL, we solved for the price of a bulb of a given wattage that results in a high probability of the bulb being identified as a CFL (90% probability). Conversely, to estimate the price of an incandescent, we solved for the price of a bulb at the same wattage that results in a low probability of being identified as an incandescent (10% probability). In other words, the price at the 10% probability corresponds to the price at which a consumer will likely choose a comparable incandescent for that particular CFL wattage. For example, we estimate the price of a 25-watt CFL to be $6.18 (price at the 90% probability level) while we estimate the price of a comparable 100-watt incandescent to be $1.78 if both bulbs are purchased at a non-big box store. (See Table 3). In part because we are relying on data collected in the first quarter of 2006, our estimated price for a 25-watt CFL is likely to be higher than current price for the same bulb as CFL prices have dropped (Table 1) We estimate that the same 25-watt CFL would cost approximately $5.21 at a big box store. As probabilities exceed the 50% level (marked with a ↕ in Table 3), the bulb is more likely to be identified as a CFL bulb, and as probabilities fall below 50%, the bulb is more likely to be identified as an incandescent. As was noted earlier, the model is not as effective at estimating prices at the lowest or highest wattages (i.e., 5 watts or 9 watts in Table 3), as all bulbs are CFLs at these low wattage levels. For ease of interpretation, Table 2 only includes non-big box stores.

Table 3: Bulb Price Estimates and Probabilities, Non-Big Box Store

Probability (Incand.<50% ; CFL >50%)	5 W CFL/ 25 W Incand.	9 W CFL / 50 W Incand.	15 W CFL / 60 W Incand.	20 W CFL / 75 W Incand.	25 W CFL / 100 W. Incand	28 W CFL / 120 W Incand.	39 W CFL / 150 W. Incand.
5%	-$7.72	-$5.97	-$3.34	-$1.15	$1.04	$2.35	$7.17
10%	-$6.98	-$5.23	-$2.60	-$0.41	$1.78	$3.10	$7.92
25%	-$5.88	-$4.13	-$1.50	$0.69	$2.88	$4.20	$9.01
↕ 50%	-$4.78	-$3.03	-$0.40	$1.79	$3.98	$5.29	$10.11
75%	-$3.68	-$1.93	$0.70	$2.89	$5.08	$6.39	$11.21
90%	-$2.58	-$0.83	$1.80	$3.99	$6.18	$7.49	$12.31
95%	-$1.84	-$0.08	$2.54	$4.73	$6.92	$8.24	$13.06

CFL Bulb Analysis

We used multiple linear regression to estimate the price difference between an ENERGY STAR CFL and a non ENERGY STAR CFL, while controlling for lumens of light output, specialty features of CFL bulbs and major manufacturers of CFL bulbs.[11] (Table 4) Data for other potentially useful features for analysis such as life cycle or color temperature were not collected. Our analysis found that there is no price difference between an ENERGY STAR CFL and a non-ENERGY STAR CFL. The incremental cost of the following independent variables is as follows:

- 1 lumen adds $.001 to the cost of a bulb
- A 3-way bulb adds $1.84 to the cost of a bulb
- An A bulb adds $1.30 to the cost of a bulb
- A Flood bulb adds $2.07 to the cost of a bulb
- Other specialty features,[12] such as Globe bulbs, add $2.14 to the cost of a bulb.

[11] All pin-based CFL bulbs were excluded from this analysis.

[12] The 'other specialty bulb' category includes the following bulbs: bullet, candelabra, globe, torpedo, candelabra and bug

- Sylvania bulbs are on average $1.36 more expensive than non-Sylvania bulbs
- Feit and Greenlite CFLs are $1.38 and $1.43 less expensive than non-Feit and non-Greenlite CFLs, respectively.

Table 4: Multiple Regression Analysis Results for Price Estimates of CFL Bulbs

		Sample CFL Bulb Prices		
Variable	**B**	**GE**	**Sylvania**	**Feit, 3-way bulb**
Number of Lumens		1200	1200	1600
Constant***	3.898	3.898	3.898	3.898
Lumens***	0.001	1.2	1.2	1.6
ENERGY STAR	0	0	0	0
GE	0	0	0	0
Commercial Electric	0	0	0	0
MaxLite	0	0	0	0
Sylvania**	1.356	0	1.356	0
Feit**	-1.379	0	0	-1.379
LOA	0	0	0	0
Greenlite*	-1.453	0	0	0
3-way bulb**	1.835	0	0	1.835
A bulb**	1.307	0	0	0
Flood***	2.067	0	0	0
Other specialty bulb***	2.136	0	0	0
TOTAL COST		**$5.10**	**$6.45**	**$5.95**

* significant at $p < .1$; ** significant at $p < .05$; *** significant at $p \leq .002$

For example, a standard 1200-lumen GE CFL bulb with no specialty features is estimated to cost $5.10, while a comparable Sylvania bulb is estimated to cost $6.45. A 1600 lumen Feit 3-way bulb is expected to cost $5.95. The incremental cost per lumen is $0.001 (e.g., 1200 lumens x $0.001 = $1.20, and 1600 lumens x $0.001 = $1.60), a figure that might used to develop incentive levels. Table 5 below shows prices for "generic," non-branded CFLs of various lumen levels. Similarly, the incremental cost is $1.84 for a three-way bulb, $1.31 for an A bulb, and $2.07 for a flood.

Table 5: Prices of "Generic" CFLs at Various Lumen Levels

Number of Lumens		**800**	**1000**	**1200**	**1500**	**1800**	**2500**
Constant***	3.898	3.898	3.898	3.898	3.898	3.898	3.898
Lumens***	0.001	0.8	1	1.2	1.5	1.8	2.5
TOTAL COST		**$4.70**	**$4.90**	**$5.10**	**$5.40**	**$5.70**	**$6.40**

We used multiple linear regression to estimate the price difference between pin-based and screw based CFL, while controlling for lumens of light output, specialty features of CFL bulbs and major manufacturers of CFLs. (Table 6) Our analysis found that screw based CFL bulbs are $1.22 less expensive

than a similar pin-based CFL. All variables that were significant in the ENERGY STAR analysis were significant in this model except for three-way bulbs.[13]

Table 6: Multiple Regression Analysis Results for Price Estimates of CFL Bulbs, Comparing Screw and Pin Based CFLs

		Sample CFL Bulb Prices		
Variable	**B**	**Commercial Electric, pin base**	**Feit flood lamp, screw base**	**Commercial Electric, screw base**
Number of Lumens		950	950	800
constant**	4.107	4.107	4.107	4.107
lumens**	0.001	0.95	0.95	0.8
Screw Or Pin Bulb*	-1.227	0	-1.227	-1.227
GE	0	0	0	0
Commercial Electric	0	0	0	0
MaxLite	0	0	0	0
Sylvania*	1.61	0	0	0
Feit*	-1.292	0	-1.292	0
LOA	0	0	0	0
Greenlite*	-1.505	0	0	0
3-way bulb	0	0	0	0
A bulb*	1.358	0	0	0
Flood**	2.102	0	2.102	0
Dimmable	0	0	0	0
Other specialty bulb**	2.398	0	0	0
TOTAL COST		$5.06	$4.64	$3.68

* significant at $p < .05$; ** significant at $p < .001$

In summary, the findings to our research questions are as follows:

1. The estimated incremental price of a 25-watt CFL over a 100-watt incandescent is $4.39.
2. Among CFL bulbs:
    a. The incremental cost per lumen for a CFL is estimated at $0.001, such that a "generic" non-branded CFL of 1200 lumens costs $5.10, while a similar CFL of 2500 lumens costs $6.40.
    b. There is no measurable price difference ($0) between an ENERGY STAR CFL and a non-ENERGY STAR CFL
    c. The estimated cost of a screw-based CFL is $1.22 less than a pin-based CFL.
    d. The estimated incremental cost of a three-way bulb is $1.84, $1.31 for an A bulb, and $2.07 for a flood.

[13] It is important to note that there is some autocorrelation of the residual terms in this model. Autocorrelation can result in regression coefficients that are unbiased but not efficient; in other words, estimated standard errors of coefficients can be underestimated, making the coefficients seem more accurate.

Conclusion

There are certainly signs of progress toward market transformation of the CFL market in Massachusetts. For example, sales of ENERGY STAR-qualified CFLs outside the program appear to be about as great as the sales inside the program (possibly stimulated by the program). In addition, four out of five consumers are familiar with CFLs; and more than one-half of all households are currently using at least one CFL. While the estimated price difference between a 25-watt CFL bulb and a 100-watt incandescent is down to $4.39, CFL prices remain a barrier to even more widespread adoption according to retailer and customer interviews.[14]

Results from this analysis will serve as a baseline of price differentials between CFL and incandescent light bulbs, helping to track the market transformation of the Massachusetts residential lighting market. In addition, this analysis can help program managers determine appropriate incentive levels for CFL light bulbs. While program managers often depend upon anecdotal or gut level estimates of appropriate incentive levels, this analysis can provide a more rational basis for setting incentive levels. This paper also suggests that future research efforts might include data for other potentially useful features for analysis such as life cycle or color temperature for CFLs and data on specialty incandescent bulbs.

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