Turning On and Tuning In: Is There a Price Premium for Energy Efficient Televisions?

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ABSTRACT

Televisions are ubiquitous in American homes and are significant consumers of energy. Utilities in nine states and British Columbia currently offer incentives ranging from $5-$50 for ENERGY STAR certified televisions. Rapid changes in the television market, driven by shifts in the prevalent basic technologies, added features, and time effects on price, mean the questions of whether and how much consumers are willing to pay a price premium for efficiency are difficult to answer. Indeed, with four versions of ENERGY STAR criteria having already come along over the past six years, and another currently in development, televisions have experienced the single most rapidly changing qualification requirements among ENERGY STAR certified products. Using comprehensive television point-of-sales data in California over a three-year period (approximately 10,507 observations representing 5.5 million units, with 46 tracked variables per unit), we have developed a hedonic price regression model that disaggregates the role of individual features (including energy efficiency), in driving the prices of televisions. We compare our results to the methods and findings of the other significant efforts to date, and discuss the implications for program design looking forward that come from our findings. Specifically, with the rising efficiency floor for televisions dictated by California's Title 20, the diversification written into ENERGY STAR v4.0 and higher to accommodate products with Automatic Brightness Control, and shifting market shares for the major television technologies, we shed some light on the analysis tasks that lie ahead from an incremental cost standpoint for this rapidly changing market.

Introduction

Televisions are an important energy consuming end use in American homes. There are approximately 338 million televisions in American homes (CEA 2013), meaning there is more than 1 television per American. All told, televisions consume approximately 30 billion kWh of electricity per year in the U.S (Ecova 2013).

Size of and Trends In the Televisions Market

The television market has undergone dramatic changes in recent years with the phase-in of digital-only signal transmission, the associated retirement of cathode ray tube televisions, and advances in flat-screen display technology. To put the current television market and trends into perspective, Table 1 below shows the market share of televisions sold in California by type. Liquid crystal display (LCD) televisions account for approximately 91 percent of new television sales, with plasma televisions accounting for a 9 percent share. However, within LCD televisions, the market share of light emitting diode (LED) backlit units has grown strongly over the past two years, while the market share of cold-cathode fluorescent lamp (CCFL) backlit units appears to be declining.

Table 1. Relative sales volume of televisions sold in California by type[1], 2010-2012

Quarter/ Year	LCD		Plasma	Portable	Rear Projection
	CCFL	LED			
Q1 2010	81.3%	7.9%	10.4%	0.00%	0.44%
Q2 2010	71.4%	14.7%	13.4%	0.00%	0.42%
Q3 2010	65.9%	19.2%	14.6%	0.01%	0.32%
Q4 2010	66.5%	22.2%	11.1%	0.07%	0.22%
Q1 2011	59.9%	26.1%	13.6%	0.05%	0.36%
Q2 2011	51.8%	33.4%	14.3%	0.20%	0.34%
Q3 2011	45.2%	39.1%	15.3%	0.16%	0.27%
Q4 2011	47.9%	36.2%	15.8%	0.07%	0.02%
Q1 2012	48.4%	37.2%	14.4%	0.05%	0.01%
Q2 2012	41.7%	46.9%	11.2%	0.06%	0.04%
Q3 2012	37.5%	53.8%	8.5%	0.04%	0.03%

(source: NPD Group, Inc. 2012)

Existing Incentive Programs for Energy Efficient Televisions

A number of public administrators (i.e. utilities and other bodies overseeing incentive programs) in the U.S. and Canada have incentive programs in place that aim to promote the spread of energy efficient televisions in the marketplace. Ten public administrators in the U.S. and Canada are currently running television incentive programs with incentive amounts varying from $5-$50 across these programs (CEE 2013). Nine of these programs are structured as midstream programs, where the program outreach and incentive payments are targeted at the retailer level, and one pilot-level program is a downstream program, with program outreach and incentives targeted at the consumer level. For several of these programs, the financial incentive is scaled, depending on whether the television meets ENERGY STAR specifications, beats ENERGY STAR specifications by 20 percent or 35 percent, or achieves the ENERGY STAR Most Efficient designation, which is given by ENERGY STAR to those models that demonstrate the leading edge in energy efficiency for their product category.

History of the ENERGY STAR Televisions Specification

The first specifications for ENERGY STAR televisions were announced in 1998 and were focused on sleep-mode (aka standby mode) power. In the intervening years, successive ENERGY STAR specifications have iteratively raised the bar on television energy efficiency using a tight timescale. As shown in Table 2 below, Versions 3.0 and higher of the ENERGY STAR televisions specification moved beyond focusing on sleep-mode power to also incorporate on-mode power as a function of screen area into the overall specification. Versions 4.0 and higher also set out specifications for televisions that have Automatic Brightness Control (ABC) as a default setting.

[1] OLED (Organic Light Emitting Diode) televisions were also tracked but represented less than 0.001% of overall unit sales in the purchased dataset and were not included in the price modeling study. Note that this technology is rapidly rising in importance and demonstrates an example of the fast-paced changes that take place in the televisions market.

Table 2. History of ENERGY STAR specifications for televisions

ENERGY STAR Version	Effective Date	Screen Size (area A in square inches)	Maximum Standby Mode Power	Maximum On Mode Power Usage (P in Watts)
1	Jan. 01, 1998	All Sizes	3 W	No Requirement
2	July 1, 2005	All sizes	1 W	No Requirement
3	Nov. 1, 2008	Non HD televisions (≤ 480 vertical res): All Sizes	1 W	P = 0.120*A + 25
		HD televisions (> 480 vertical res): A < 680		P = 0.200*A + 32
		680 ≤ A < 1045		P = 0.240*A + 27
		A ≥ 1045		P = 0.156*A + 151
4	May 1, 2010	A < 275	1 W	P = 0.190*A + 5
		A ≥ 275		P = 0.120*A + 25
		televisions with Automatic Brightness Control (ABC, default): All Sizes, per above specs[2]		P = (0.55 * P300_lux) + (0.45 * Pzero_lux)
5	May 1, 2012	A < 275	1 W	P = 0.130*A + 5
		275 ≤ A ≤ 1068		P = 0.084*A + 18
		A > 1068		P = 108
		televisions with Automatic Brightness Control (ABC, default): All Sizes, per above specs		P = (0.55 * P300_lux) + (0.45 * Pzero_lux)
6	June 1, 2013	All Sizes	1 W	P =100 × tanh(0.00085 × (A -140) + 0.052) +14.1
		televisions with Automatic Brightness Control (ABC, default): All Sizes, per above specs		P = (0.25× P100_lux) + (0.25× P35_lux) + (0.25× P12_lux) + (0.25× P3_lux)
7	Specification Development Launch and Data Assembly - December 2, 2013			

Source: ENERGY STAR 2013

The Challenge of Estimating Incremental Cost for Energy Efficient Televisions

One area of controversy regarding energy efficiency incentive programs for televisions is the development of a rigorous estimate of a price premium (or incremental cost), if it exists, that is specifically associated with higher efficiency televisions. This is a critical piece of information for utility program design, as it forms the basis around which to structure appropriate program

[2] Lux is the SI unit of illuminance, equal to one lumen per square meter. Terms including lux in the algorithms for ENERGY STAR Versions 4 and higher represent the measured On Mode power with Automatic Brightness Control enabled when tested at a given ambient light level.

incentives. Because televisions are part of a rapidly changing and diversifying technology space, it is a time- and resource-intensive process to disentangle the role of energy efficiency in driving the price of a television, relative to the many other features that contribute to price. This is further confounded by the backdrop of rapidly falling prices for a given television technology over time, through economies of scale and the continual introduction of substitute products in the market with increased features.

Few incremental cost studies for televisions have been conducted. DisplaySearch.com is an online resource for television cost and price forecasting based on data collected by the NPD Group, Inc., (formerly National Purchase Diary), a market research company that provides market information and advisory services to companies. NPD makes reports available for purchase. This resource has been used to estimate incremental cost for potential efficiency improvements in televisions such as dual brightness enhancement film and screen dimming (Park et al. 2011).

Some public administrators have used the average difference in price between separate television technologies, such as cold-cathode fluorescent light (CCFL) and LED-backlit units of similar size, as a proxy for estimating incremental cost. In California, the investor-owned utilities have historically cited difficulties in accurately determining incremental cost for ENERGY STAR certified televisions and have based their programs on the difference in average prices between CCFL- and LED-backlit units. Across the range of public administrators in the U.S. and Canada with energy efficiency programs for televisions in place, it is not clear what data underlies the incremental cost estimates and with what level of rigor this data has been analyzed. The Massachusetts and Rhode Island programs offer $5-$25 incentives for ENERGY STAR televisions, $10-$50 for ENERGY STAR Most Efficient, and cite the ENERGY STAR Consumer Electronics Calculator as the basis for incremental cost information, yet the Consumer Electronics Calculator displays a default incremental cost for televisions of $0 and lists "EPA research on available models, 2012" as its own data source (CEE 2013).

The analytical work covered in this paper stems from a large-scale study conducted by Itron for the California Public Utilities Commission (CPUC) investigating the incremental cost of over 100 measures offered in utility programs in California. [3]

Methodology

To develop price models for estimating incremental cost, we acquired comprehensive television point-of-sales (POS) data in California over a 2.75 year period from the NPD Group. This dataset included 46 product characteristics for each record, along with the average actual selling price in each of 11 quarters (Q1 2010 through Q3 2012). Due to the comprehensiveness of the NPD POS data, the data development efforts focused primarily on working with NPD to limit the number of records whose detailed information was "masked" in order to conform to NPD's confidentiality agreements with its respective retail partners. We spot checked characteristics in the purchased dataset against online retail lookups and also visually verified values in the purchased dataset against the expected range for each feature.

The originally purchased dataset contained records for the sale of 7.9 million units representing approximately 80 percent of the entire CA market from 2010 Q1 through 2012 Q3. However, detailed product characterization information necessary for model development was

[3] The full report is available at: http://www.energydataweb.com/cpucFiles/pdaDocs/1100/2010-2012%20WO017%20Ex%20Ante%20Measure%20Cost%20Study%20-%20Final%20Report.pdf

only available for TV models that had met ENERGY STAR Version 3.0 criteria or higher. This restricted the usable dataset to 10,507 records representing sales of 5.5 million units from 2010 Q1 through 2012 Q3. Of these, 14 percent were Version 3.0 certified, 55 percent were Version 4.2 certified, and 30 percent were Version 5.3 certified units.

Hedonic Price Modeling

Once the raw television price data had been validated, we then developed and tested econometric regression models of television prices, often referred to as hedonic price models. This method uses a statistical regression approach to isolate and estimate the relative influence of various individual product features on a product's final, observed price. In essence, the regression produces a best fit equation for how variability in television price can be accounted for by variability in each of the independent variables in the dataset, including the specific variables of interest in this study: on-mode power and standby power. The outcome of the regression can be expressed as an equation of the form

$$Price = a_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_nX_n + \varepsilon$$

In this equation, X_1, X_2, …X_n, etc. represent different independent variables that may drive the price of televisions, such as brand, size, TV type, picture-in-picture, and various other features. The b_1, b_2, …b_n terms represent the coefficients associated with each feature (i.e. the number of dollars of price change associated with a step change in the value of a given independent variable). The a_0 term represents the intercept (i.e. the basic cost of a TV irrespective of features that add additional cost) and ε is an error term in the regression. Variables in the dataset were characterized in the regression either as continuous numeric (e.g. screen size), categorical (e.g. brand), or binary (e.g. presence/absence of 3D viewing capability).

The coefficient for each variable in the equation has an associated t-stat showing the statistical strength of its correlation with price, and the overall equation can be characterized with the coefficient of determination, R^2, which indicates the proportion of price variation explained by variation in the independent variables in the model.

Collinearity

The biggest single challenge in this model development process is identifying and minimizing collinearity among independent variables. Multiple product characteristics may be collinear, i.e., tend to move together with respect to price. For example, on-mode power consumption and screen size for televisions represent collinear variables (i.e., larger televisions have higher on-mode power requirements).

Econometric models that include highly collinear variables will produce estimated coefficients that are not precisely estimated. Specifically, including highly collinear variables in a model can yield erratic behavior in the sign and magnitude of model coefficients because the regression function is effectively forced to arbitrarily assign coefficients to each component in a covarying set of variables. In principle, greater multi-collinearity within a model will result in larger estimated standard errors of the coefficients and reduced statistical significance. However, because there is virtually always some degree of correlation between most pairs of variables in a dataset, collinearity can never be eliminated. As such, collinearity tolerated in a regression model is a matter of degree, and there is no threshold value for an "acceptable" level of multi-collinearity. Rather, there is a subjective tradeoff between the number of explanatory variables and the degree of collinearity tolerated in the model, and the modeler's task is to maximize the specificity of the model while minimizing collinearity.

Model Development Approach

To develop our hedonic price regression models for televisions, we used a stepwise approach in which we started with just a single independent variable in a model run, added one additional independent variable to the regression in each successive model run, and observed the resulting coefficients, t-stats, and R^2 values. Through a trial and error process, we looked to develop a stable series of model runs in which the coefficients for each independent variable smoothly decline in value as additional explanatory variables are added to the model (since the "pie" of total cost is divided among a progressively larger number of explanatory "wedges" with increasing specification of the model). The end goal of the process was a maximally specified model in a stable and intuitively sensible set of model runs, with due diligence showing that none of the additional variables in the dataset add statistically significant predictive power to the model.

Results

For brevity, an overview of the results from the intermediate modeling steps is provided here, along with tables showing final model results for each combination of TV type and screen size. Comprehensive presentation of all final model results can be found in the final project report prepared for the CPUC.

We initially developed a single regression model from the entire dataset, including all television types. In this model, television type was included as a categorical variable, and energy efficiency was expressed as the percent by which a given model was more efficient than the California Code of Regulations Title 20 requirement for maximum on-mode power as a function of screen area. All 11 quarters of data were included in the model, and time period was treated as a categorical variable with a set of 11 dummy variables (i.e. a set of presence/absence binary variables) representing each quarter in the dataset. Results from the initial regression models on the entire dataset showed relatively low R^2 values (approximately 0.39), large swings in coefficient values as additional explanatory variables were added to the model specification, and large magnitude coefficients for television type.

In the next set of model runs, we restricted the dataset to the two dominant screen resolutions (1366 x 768 and 1920 x 1080 native resolution, representing 41 percent and 49 percent of the units in the overall dataset, respectively), incorporated screen resolution as a categorical variable in the model, and added backlight source (LED, CCFL, Lamp) as an additional categorical variable. The R^2 went up to approximately 0.76, but the coefficients on the energy efficiency variables were erratic across model runs.

In the next phase, diagonal screen size was included as a continuous numeric variable, seasonal price effects were addressed with a set of four dummy variables representing the four seasons (regardless of year), and we shifted to characterizing energy efficiency as on-mode power (W) rather than percent better than Title 20. We also restricted the dataset to the final eight quarters of data to reduce the time effects on price that are not captured in the seasonal price effects dummies. This yielded R^2 values of approximately 0.78 and increased stability of the coefficients across model runs. The next model iterations incorporated the presence/absence of 3D viewing capability, as well as 4 color pixels (including yellow in addition to standard Red-Green-Blue), and the R^2 value increased to 0.81.

Importantly, at this stage the model displayed good levels of model fit, as illustrated by the very high R^2 values, and intuitively sensible and stable coefficients, *with the key exception being a small, non-statistically significant negative incremental cost for on-mode power (i.e. higher prices for less efficient units, all else being equal)*. The remainder of the entire modeling exercise that follows can effectively be characterized as a process of determining whether this finding of zero incremental cost for energy efficiency in televisions would hold up under progressive narrowing and segmenting of the dataset to minimize collinearity issues that could be driving the initial result.

In order to determine if this was a real effect, the study team decided to generate separately specified models for subsets of the overall data broken out by TV type and specific screen size. This completely eliminated variability in TV type and screen size within a given smaller model and effectively sidestepped the issue of collinearity between TV type, screen size, and the energy efficiency variables. We could then look across the final versions of these submodels for possible patterns in coefficients across TV type and size.

In this narrowing and subsetting process, we first built a model specifically for all LCD televisions (CCFL- and LED-backlit). These model runs yielded stable and intuitive coefficients for most variables and yielded a similar small, non-statistically significant negative incremental cost for on-mode power.

Next we narrowed the model to focus on LED-backlit LCD televisions (hereafter referred to as LED televisions). We experimented with characterizing screen size as a categorical rather than continuous variable by using a set of size bins corresponding to the measure definitions in the California utility workpapers. However, the cleanest model runs came from keeping screen size as a continuous numeric variable. These model runs yielded R^2 of approximately 0.86, with coefficients for all of the most significant drivers of television cost showing stable and intuitively sensible patterns of steady decline across model runs. These included display size, presence/absence of picture-in-picture feature, 3D viewing capability, presence/absence of DVD, networking capability, seasonal effects on price, and brand. The small, non-significant, negative incremental cost persisted through this narrower specification of the model.

Having seen the absence of a meaningful incremental cost signal persist through segmentation of the dataset down to LED televisions only, the last major step for LED televisions was to completely isolate screen size. To achieve this, we built stand-alone regression models for each of the six most common LED screen sizes that collectively covered the range of screen size in the full dataset. The screen sizes with the largest share of unit sales in the dataset were 19 inches, 22 inches, 32 inches, 40 inches, 46 inches, and 55 inches (collectively representing 68 percent of all units in the LED dataset). We took the set of initial model specifications that were applied to all LED screen sizes together and re-estimated those models using the screen size-specific datasets. The individual screen size-specific models were then customized to account for price-influencing attributes that are unique or prevalent within specific screen sizes (e.g. 480 Hz refresh rates for large screens, 1366 x 768 native resolution for smaller screens, etc.). We built parallel sets of these models for the last 8 quarters of data and for the final year of data and noted that the results were very comparable. The tables that follow show the results from the models built on the final year of data. Table 3 below shows the final model coefficients for each size of LED television. Looking across television sizes we see how the counterintuitive result of a higher cost per watt for on-mode power persisted at this highest level of model subsetting. We see lower cost per increasing wattage in sleep mode (i.e., the intuitively expected price premium for lower sleep mode power), and we see the various other characteristics impacting price in each size-specific model. Season was a consistently significant driver of price across all sizes, and other television features played a significant role in driving price for some sizes but not others.

Table 3. Final model results for LED-backlit LCD televisions

TV Characteristic	Screen Size (diagonal inches)					
	19"	**22"**	**32"**	**40"**	**46"**	**55"**
Model fit: R^2	**0.904**	**0.873**	**0.93**	**0.91**	**0.88**	**0.753**
Intercept	64.89	130.34	435.93	238.74	674.97	2,236.83
On-mode Power in W	1.03 (1.63)	1.10$^{\#\#}$ (2.65)	1.65 (1.31)	3.40$^{\#\#\#}$ (3.08)	1.76 (1.13)	0.89 (0.43)
Sleep-mode Power in W	-6.28 (-0.15)	-90.09$^{\#\#\#}$ (-2.76)	-115.31$^{\#\#\#}$ (-2.93)	-144.21 (-1.24)	-223.73 (-1.51)	-90.97 (-0.31)
Additional independent variables in final model	Brand* Quarter* DVD Included* USB Interface	Brand* Quarter* DVD Included* Network Connectivity* Resolution* Removable Media Apps Included	Brand Quarter* DVD Included Network Connectivity USB Interface Resolution* 2D vs 3D* Program Guide	Brand* Quarter* Network Connectivity Apps Included 2D vs 3D*	Brand* Quarter* Network Connectivity Apps Included 2D vs 3D* Refresh Rate (Hz)* Picture in a Picture Analog Tuner	Brand Quarter* Network Connectivity* 2D vs 3D* Program Guide Refresh Rate (Hz)*

note: t-statistic is in parentheses
note: ### $p<0.01$, ## $p<0.05$, # $p<0.1$
note: * $p<0.1$ for one or more of the discrete values that these categorical or binary variables can take on

We then applied this same approach to CCFL-backlit LCD televisions for the same six specific screen sizes. As with LED televisions, the same six screen sizes represented the majority of unit sales in the dataset (collectively representing 73 percent of all units in the CCFL dataset), and the individual screen size-specific CCFL models were customized to account for price-influencing attributes that are unique or prevalent within specific screen sizes.

Table 4 below shows the final model coefficients for each size of CCFL television. On-mode power did not show a statistically significant relationship to price across screen sizes, and sleep mode power behaved intuitively. The other independent variables played a significant role in driving price for some sizes and not others.

Table 4. Final model results for CCFL-backlit LCD televisions

TV Characteristic	Screen Size (diagonal inches)					
	19"	**22"**	**32"**	**40"**	**46"**	**55"**
Model fit: R^2	**0.963**	**0.726**	**0.956**	**0.962**	**0.968**	**0.922**
Intercept	100.79	221.89	173.27	667.20	994.11	1,048.45
On-mode Power (W)	2.10### (6.40)	-0.55 (-0.26)	1.34### (3.74)	-0.14 (-0.37)	-0.25 (-0.34)	-1.18### (-2.73)
Sleep-mode Power (W)	-6.12 (-0.41)	-100.44 (-0.81)	-43.97 (-1.24)	-86.11 (-1.08)	-142.83 (-0.90)	-161.16### (-3.14)
Additional independent variables in final model	Brand* Quarter* DVD Included* USB Interface*	Brand* Quarter DVD Included* Resolution*	Brand* Quarter* DVD Included* Network Connectivity* USB Interface* Resolution* 2D vs 3D* Program Guide*	Brand Quarter* DVD Included Network Connectivity* Refresh Rate (Hz) Analog Tuner*	Brand* Quarter* Network Connectivity* Apps Included 2D vs 3D* Refresh Rate (Hz) Picture in a Picture* Analog Tuner Advanced Proprietary OS	Brand* Quarter* Network Connectivity* USB Interface Apps Included 2D vs 3D Program Guide Refresh Rate (Hz)

note: t-statistic is in parentheses
note: ### p<0.01, ## p<0.05, # p<0.1
note: * p<0.1 for one or more of the discrete values that these categorical or binary variables can take on

Plasma Televisions

We also built a regression model that focused specifically on plasma televisions. This was a single model across all sizes of plasma televisions but otherwise followed the same trial and error process of stepwise model development described for the other TV types.

For plasma televisions, coefficients on the major price driving variables generally behaved intuitively, without major collinearity issues, even when including all plasma televisions in the same dataset and treating diagonal screen size as a continuous numeric variable. As shown in Table 5 below, plasma televisions showed the same absence of incremental cost for reductions in on-mode power that was observed for LCD televisions and actually showed a negative incremental cost of $5.80/watt that was significant at the 1 percent level. The relationship between sleep-mode power and price is not statistically significant for plasma televisions, and the magnitude of the coefficient is $40/watt.

Table 5. Final model results for plasma televisions

TV Characteristic	**All Screen Sizes**
Model fit: R^2	**0.792**
Intercept	-1,459.92
Display size (inches diagonal)	25.27### (9.15)
On-mode Power (W)	5.80### (10.24)
Sleep-mode Power (W)	-40.08 (-0.77)
Additional independent variables in final model	Brand* Quarter* Resolution* 2D vs 3D*

note: t-statistic is in parentheses
note: ### p<0.01, ## p<0.05, # p<0.1
note: * p<0.1 for one or more of the discrete values that these categorical or binary variables can take on

Overall, the largest single result of building separate, individually specified regression models was to confirm what had been observed at a preliminary level in earlier models, that on-mode and sleep mode power are generally non-significant factors in driving the price of televisions. As summarized in Table 6 below, the correlation between on-mode power and price is not consistent enough across sizes within a given television type to form the basis for asserting a meaningful relationship between energy efficiency and price. The only consistent finding for televisions is a non-statistically significant, negative incremental cost, i.e. higher average prices for higher on-mode power consumption.

Table 6. Coefficients, t-Statistics, and standard error for on-mode power and sleep mode Power[4]

TV Type	Display Size	On-Mode Power			Sleep-Mode Power		
		Coefficient	T-stat	s.e.	Coefficient	T-stat	s.e.
LED	19"	1.03	1.63	0.63	-6.28	-0.15	41.84
	22"	1.10	2.65	0.41	-90.09	-2.76	32.65
	32"	1.65	1.31	1.26	-115.31	-2.93	39.40
	40"	3.40	3.08	1.10	-144.21	-1.24	116.69
	46"	1.76	1.13	1.56	-223.73	-1.51	148.32
	55"	0.89	0.43	2.08	-90.97	-0.31	295.72
CCFL	19"	2.10	6.40	0.33	-6.12	-0.41	14.80
	22"	-0.55	-0.26	2.11	-100.44	-0.81	123.24
	32"	1.34	3.74	0.36	-43.97	-1.24	35.36
	40"	-0.14	-0.37	0.38	-86.11	-1.08	79.49
	46"	-0.25	-0.34	0.74	-142.83	-0.90	158.61
	55"	-1.18	-2.73	0.43	-161.16	-3.14	51.30
Plasma	All Sizes	5.80	10.24	0.57	-40.08	-0.77	51.95

Conclusions

This study represented an important opportunity to take an in-depth look at the relationship between energy efficiency and the price of televisions using a comprehensive POS dataset of television sales in California from 2010 through 2012. Using regression-based hedonic price modeling and a multitude of segmentation approaches, we found and confirmed that there is no statistically significant evidence of incremental costs related to on-mode power or sleep mode power among any of the major television types that dominate the current market. Indeed, LED and CCFL backlit LCD televisions show a small, non-statistically significant negative incremental cost associated with on-mode power. This effect bears up across all levels of model specification and across television sizes despite variations in the sets of features that drive price in each size class. Plasma televisions also exhibit negative incremental costs with respect to on-mode power, and this effect is statistically significant at the 1 percent level.

To be clear, our findings are specific to the relationship between price, on-mode power, and sleep mode power. Looking forward, however, both television technology and ENERGY STAR product specifications are trending towards a focus on the interactions between energy consumption and automatic controls. In this sense, the question of "what is the incremental cost

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[4] Other variables controlled for in the models include: Brand, DVD Included, USB Interface, Quarter, Resolution, Removable Media, Network Connectivity, Apps Included, 2D vs 3D, Program Guide, Refresh Rate (Hz), Picture in a Picture, Analog Tuner, Advanced Proprietary Operating System. Variables also tested but dropped due to having no significant impact on television price (or due to having a high degree of collinearity with other, more central variables in the dataset) include: Browser Installed, Hard Drive Included, Hard Drive Recorder Included, Internet Connection Type, Number of HDMI Connectors, A/C Power Source, Cable Card Slot Included, Digital Interface Included, Number of ATSC Tuners, Removable Media Type.

of an energy efficient television?" is already expanding beyond the relationship between price and rated on-mode and standby power.

Indeed, answering that question on a going-forward basis will continue to pose significant challenges to program administrators trying to design incentive programs and assess cost-effectiveness. More specifically, as the ENERGY STAR product specification for televisions moves towards performance metrics that require standard test conditions and procedures, there is likely to be a continual gap between the product performance data available for ENERGY STAR-compliant products and those available for non-compliant, baseline-efficiency products for which such testing is not conducted. Conceptually, one possible solution to this issue would be for the US EPA to work with the US DOE (or in the case of televisions, the California Energy Commission) to incorporate the ENERGY STAR test procedures into those required for compliance with federal (or state) appliance standards, as an information-only reporting requirement. Such an approach would then make such test-based performance data available for all products.

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