CITIZENS WANT REGULATION AFTER SEEING BRIGHT FUTURE OF LED LIGHTING

by

JARED DANIEL

(Under the Direction of William Secor)

ABSTRACT

As food producers turn to controlled environment agriculture (CEA) to feed growing populations while facing decreasing arable land acreage, climate change, and other challenges, it is crucial to understand externalities associated with controlled environment agriculture. The use of efficient and versatile light-emitting diode (LED) supplemental lighting systems for increased profits for those producers presents a unique set of externalities including light pollution. Using an online survey and Tobit model, the authors find that after showing individuals images of light pollution from supplemental LED lighting sources, most survey participants want more regulation of those sources. The most popular candidate for regulation of LED lighting systems among participants in this study is state government. There are several significant factors influencing survey respondents' post-treatment preference outcomes for different levels of regulation and regulators including demographic characteristics as well as initial attitudes towards LED lighting systems before treatment.

INDEX WORDS: LED lighting, regulation, externalities, controlled environment agriculture, tobit

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DEDICATION

I dedicate this thesis to my family and friends who have encouraged me along the way. I love you all and could never have finished my MS without you.

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I would like to thank Dr. Will Secor for the help he has given me in writing this thesis. Dr. Secor, your patience, helpfulness, and proficiency are characteristics I hope to emulate in my career. I would also like to thank Dr. Ben Campbell for his instruction, assistance, and for allowing me to be a part of this project. I would also like to thank Ben for the help he has given me beyond academics with job interview prep and career advice. Thank you also to Dr. Julie Campbell for taking the time to be a part of this project. My graduation and my future would not be possible without the people mentioned above, and I am incredibly grateful for them.

Thank you to the professors who contributed to my education at the University of Georgia both as an undergraduate and graduate student. Please never undervalue the impact of your guidance, instruction, and encouragement of students. Research, as you are aware, is vital. Your field of study will most likely not soon run out of important questions to answer. However, in my own humble opinion, teaching the next generation of professionals is of equal importance. Your students appreciate and look up to you just as much as any journal or others in your field (maybe more so). Thank you for the work you do not only as academic pioneers, but also as educators.

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CHAPTER 1

INTRODUCTION

Agriculture today faces numerous challenges including climate change, decreasing acreage of arable land, fresh water supply concerns, and population growth (Fedoroff, 2015). One solution to the issue of decreasing acreage of land suitable for growing crops is controlled environment agriculture (CEA) which allows for highly efficient, year-round production of plants and food wherever such a facility can fit, including rural, suburban, and metropolitan areas. Greenhouse cultivation has the potential to reach yields much higher than traditional field crops of the same kind given the same acreage. CEA also has other advantages including temperature, humidity, and lighting control. One type of CEA, known as a vertical farm or indoor production facility, is particularly suited to urban areas and has several promising environmental and economic benefits, such as reduction in fossil fuels and chemical usage as well as greater immunity to pests and droughts (Benke and Tomkins, 2017). However, like most agricultural and other business ventures, CEA has its own unique set of externalities to consider when planning, investing, operating, and regulating. This paper focuses on the attitudes and regulatory preferences regarding externalities associated with supplemental lighting used in CEA.

Supplemental lighting allows controlled environment agriculturists of ornamental and edible plants to increase their profitability by shortening the growing cycle of their product. Shortening growing cycles leads to more growing cycles completed annually, which leads to increased profits. Supplemental lighting also allows producers to keep their growing cycles on schedule during unexpected weather patterns. Supplemental lighting systems also allows for the cultivation of plants year-round regardless of location and species, providing unique production and marketing opportunities for enhanced profit. There are different types of supplemental lighting systems available to greenhouse growers including LED (light-emitting diodes) and HPS (high-pressure sodium) lighting systems. This paper focuses specifically on externalities associated with LED lighting systems.

The usefulness of LED lighting for use in CEA was first researched in the late 1980s and early 1990s (Morrow, 2008). LED lighting systems have grown in popularity in recent years possibly due to characteristics such as efficiency and low maintenance cost which make them more cost-effective supplemental lighting solutions than HPS systems in certain production enterprises (Nelson and Bugbee, 2014). LEDs are energy efficient in two ways, first manifesting in the actual energy efficiency of the diodes themselves, second in the low heat output of LEDs resulting in the lower energy inputs needed for temperature control of greenhouses (Mitchell, et al., 2012). Kowalczyk et. al (2020) compared efficiency of LED and HPS supplemental assimilation lighting in greenhouse cucumber production and found LED lighting systems to be more energy efficient with higher production value and gross margins in 2015 and 2016. In the long run, LEDs allow for the reduction of production costs of vegetables compared to traditional lighting systems, such as HPS systems, due to these beneficial characteristics (Singh et al., 2014).

LEDs are incredibly versatile compared to other lighting systems and provide opportunities for highly specialized production. Due to the low heat output of LEDs, they can be placed closer to plants even at high light intensities (Olle and Viršilė, 2013). LED systems also give the grower a unique level of control over plant morphology and reproductive cycles using different spectrums of light unavailable to other lighting systems (Massa et al., 2008). Blue light has been shown to increase concentrations of nutritionally important primary and secondary metabolites in certain specialty vegetable crops (Kopsell et al., 2015). Choi et al. (2015) evaluated effects of different LED lighting colors in two different controlled environment agriculture facilities on strawberry yield and quality. Due to the variability, adaptability, and efficiency of LED lighting, greenhouse producers can incorporate sophisticated supplemental lighting programs suited to their production needs while also reducing long-term costs. As studies continue to surface exploring the exact effects of different lighting programs on edible plant growth (Lin et al., 2013 and Li and Kubota, 2009), it is likely we see increases in greenhouse producers adopting LED lighting systems to reduce costs, improve quality, and increase profits.

LED grow lighting presents a variety of possible negative externalities, especially when used during nighttime hours. Approximately 83% of the world's population and 99% of the population of Europe and the United States already experience some level of light pollution (Falchi et al., 2016). Shiftwork causing exposure to artificial light outside normal daylight hours has been linked to an increased risk of cancer due to disruption of the circadian cycle of hormone production in humans which is responsible for the production of melatonin (Hansen and Stevens, 2012). Humans are not the only organisms affected by light pollution. Artificial lighting at night (ALAN) is a large source of concern for biological rhythms and reproductive health of bird populations (Dominoni et al., 2013 and Dominoni, 2015).

In 2019, a resident of Peach County, Georgia filed a lawsuit against the Canadian vegetable company Pure Flavor due to ALAN from their large greenhouse located near county residents (13wmaz.com, 2019). Clearly, there is potential for conflict between greenhouse growers using supplemental lighting and individuals that live near them. As of April 1, 2021, Canada already has fines in place for producers who use supplemental lighting at night without blackout curtains (greenhousecanada.com, 2019). Retrofitting greenhouses with blackout curtains can be extremely costly. If consumers in the United States respond negatively to supplemental lighting, it may be beneficial for producers to incorporate blackout curtains into their startup costs to avoid costly retrofitting in the future or avoid investing in enterprises requiring supplemental lighting near established residents.

This research evaluates consumer attitudes regarding LED lighting for controlled environment agriculture and whether it should be regulated. Unique to this study, survey respondents are subjected to an information treatment, and their changes in attitudes are assessed.

The results of this study suggest that older generations and individuals unaware of their location to the nearest greenhouse are more likely to want regulation of supplemental LED lighting when exposed to media images of light pollution from those sources. The results also suggest that males, households with children, higher income households, and individuals living in metropolitan areas are less likely to want regulation after exposure to media images of LED lighting. Individuals with higher initial perceptions of LED safety were also less likely to want regulation after seeing the images of light pollution from LED supplemental lighting. The Tobit results also suggest that individuals without strong initial opinions regarding LED lighting are more likely to change their attitudes regarding regulation of supplemental LED lighting systems than those with strong initial attitudes after being shown media images of light pollution. The results of this study also suggest that most individuals want more regulation after seeing pictures of LED light pollution except for those individuals with strong initial anti-regulation preferences.

Individuals that prefer no regulation or less regulation prior to treatment seem to be strongly opposed to regulation by the federal government. Individuals that initially prefer the current level of regulation tend to not change their mind regarding who should regulate post treatment. Changes in respondent preferences regarding who should regulate also suggest that individuals with unknown preferences want the county to regulate supplemental LED lighting after seeing images of light pollution. Overall, the most popular candidate for regulation seems to be state government, while federal government is the least popular candidate.

Producers and policymakers can use the results of our research to make informed decisions about the use and regulation of LED systems for supplemental lighting and potential backlash from nearby residents.

The remainder of the thesis is structured as follows. Chapter 2 describes the data used in the study. Chapter 3 discusses the methods used to understand the data, including a Tobit model regression and an analysis of changes in regulation and regulator preferences. Chapter 4 presents and interprets the results of the study. Chapter 5 summarizes the major findings of the study and draws out implications of the results for policy makers and producers.

CHAPTER 2

DATA

Data was collected through an online survey conducted from December 2020 to March 2021. Residents from all regions of the United States participated in the survey. The most strongly represented region is the Southeastern U.S., including Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. Toluna, Inc. was the provider of random survey respondents 18 years of age or older. Toluna contacted qualifying respondents via email to invite them to participate in the survey. After accepting the invitation to participate in the survey, participants were given the survey.

Potential biases may exist due to the nature of online surveys. Selection bias may occur if participants are not selected randomly in terms of their opinions or preconceived notions regarding supplemental LED lighting in controlled environment agriculture. To combat selection bias, Toluna uses a random selection process with checks in place to ensure a representative sample of the United States is procured. To further mitigate selection bias, Toluna invites respondents to participate before they are made aware of the key topics and questions present in the survey. Another potential bias that could influence results is response bias. To combat response bias, concise language and a myriad of possible answers are provided. For example, some answers allow for the use of 0 to 100 scales, and others use more than extremes, such as "regulate" and "do not regulate" for questions concerning respondents' regulation preferences.

Demographic questions were included in the survey regarding age, education, gender, household income, and other characteristics. Additionally, questions concerning the agricultural background of the respondent such as “What is your connection to agriculture?” and “Are you the primary shopper for food in your household?” were asked. The sample is representative of several national demographic characteristics including race, age, and income. The median household income of the sample is approximately $62,500 compared to the United States Census Bureau’s (USCB) 2019 estimate of $62,843. The median age of our sample is 42, while the USCB’s 2019 median age estimate is 38.3. The difference in medians can be explained by the targeting of the survey towards individuals 18 years or older. In our sample, race consisted of 82% white, 9% African American, and 9% other race. This is close to the USCB’s estimates of 76% white, 13% black or African American, and 11% other race. Our sample consists of 39% male respondents. The USCB estimates the U.S. population to be 49.2% male. This difference can be explained by the targeting of the survey towards primary food shoppers in the household, resulting in a larger representation of women in the survey.[1] See Table 1 for an overview of all demographic characteristics.

The survey asked several questions (see Appendix A) regarding the respondents’ knowledge and opinions of supplemental lighting systems and LED lighting, such as “Have you ever heard of the following types of supplemental lighting systems used in greenhouses?” Participants marked yes or no for LED, HPS, and other. The survey also asked, “Do you know how the nearest greenhouse to you provides light to its crops?” Participants were given five choices including sunlight, LED lighting, HPS lighting, other, and “I do not know”.

The survey also gauged the respondents’ concerns regarding safety of LED lighting as well as different colors of LED lighting, and how they felt about operations using supplemental lighting in food production. Respondents were presented with “Do you think growing plants with

[1] 94% of participants claimed to be the primary food shopper of their household.

LED lights is…” and selected a number from 0 (not safe) to 100 (extremely safe) for “safe for plants?”, “safe for humans during production?”, “safe for humans when consuming produce grown using LED lights?”, “safe for humans planting plants grown using LED lights?”, and “safe for animals living around the greenhouse?” Participants selected a number from 0 (extremely unconcerned) to 100 (extremely concerned) for red, blue, white, yellow, orange, and other LED light colors to answer the question “LED lights come in different colors, how concerned would you be about living near a greenhouse producer that uses the following colors of lights?”

Participants were asked “Which of the following do you think are advantages of using LED lighting in a greenhouse?” to which 10 answers were available for choosing, including “better energy efficiency than other supplemental lights”, “fewer greenhouse emissions”, “change bulbs less often”, “do not contain mercury in the lights”, “do not contain copper in the lights”, “do not contain lead in the lights”, “do not contain nickel in the lights”, “allows for year round production”, “other”, and “I do not know.” A few potential answers to this question are not true and are, in fact, disadvantages of LED lighting. LED lighting is more energy efficient than other supplemental lights (Singh et al., 2015). LED lighting fixtures have very little emissions beyond visible light and result in less carbon emissions due to their increased energy efficiency (Bessho et al., 2011). In addition, LED lights do not contain mercury and are able to maintain useful levels of output for long periods of time without replacement (Morrow, 2008). However, LED lighting may contain large amounts of copper, nickel, and lead which have potential environmental and health risks.

LED lighting systems had been heard of by 66% of respondents. However, 57% of survey participants did not know how the nearest greenhouse to them provided light to its crops.

Overall, respondents felt that LED lighting systems were slightly safer than "somewhat safe". The highest mean answer concerning safety of LEDs was for plants (68%), and lowest was for animals living near the greenhouse using LEDs (63%). The most common advantages of using LED lighting in a greenhouse cited by the respondents included better energy efficiency (49%), year-round production (53%), and the changing of bulbs less often (41%). Survey participants were not concerned about living near a greenhouse producer using any one color of light. The highest mean level of concern was 53% for red LED lights. The lowest mean level of concern of 50% was for white LED lights.

The focus of this paper is the effect of a treatment in the form of media images of light pollution on respondents' preferences for LED regulation and what entities should be responsible for such regulation. After giving answers to the questions below, participants were shown media images of light pollution from producers using LED supplemental lighting systems (Appendix C). Then, the respondents were asked the same questions a second time, after they saw the images of light pollution from the use of LED lighting.

A series of questions were given to participants regarding their preferences for regulation of LED lighting (see Appendix B) before and after the media images discussed above. Participants answered, "How do you feel about greenhouse operations using supplemental lighting in their production?" on a scale of 0 (should never be allowed) to 100 (should always be allowed). Participants were also asked more specific questions concerning regulation of LED lighting for food production and who should be responsible for such regulation before and after the treatment was administered. "Should there be regulations on using supplemental lighting technologies for growing plants for food (e.g., tomatoes, cucumbers etc.) in greenhouses?" Available responses were "do not regulate," "regulate less," "regulate the same amount" "regulate more" and "I do not know." Lastly, respondents were asked "Who should be responsible for regulating supplemental lighting technologies for growing plants for food (e.g., tomatoes, cucumbers, etc.) in greenhouses?" Response options were "City/Municipal government," "County government," "State government," and "Federal government." Respondents could select as many or as few options as they would like.

Table 1. Descriptive statistics of survey respondents' demographics

Variable	Mean	Std. Dev
Region		
Far west	14%	-
Great lakes	15%	-
Mideast	19%	-
New England	5%	-
Plains	5%	-
Rocky Mountains	3%	-
Southeast	28%	-
Southwest	11%	-
Metropolitan, Suburban, or Rural		
Metropolitan	25%	-
Suburban	54%	-
Rural	21%	-
Age	45	17
Median Age	42	-
Generation		
Older	29%	-
Gen X	29%	-
Younger	42%	-
Percent Male	39%	-
Race		
African American	9%	-
White/Caucasian	82%	-
Other Race	9%	-
Political Affiliation		
Democrat	43%	-
Republican	29%	-
Other	28%	-
Education		
High school or less	15%	-
Some college	31%	-
Bachelor's degree	31%	-

Graduate degree	23%	-
Number of adults in household	2.2	1.0
Number of children in household	.8	1.2
Household income (dollars)	$74,728	$38,572
Household income median (dollars)	$62,500	-
Connection to agriculture		
Great grandparents grew up/worked on a farm	43%	-
Grandparents grew up/worked on a farm	48%	-
Parents grew up/worked on a farm	34%	-
You grew up on a farm	16%	-
You currently work on a farm	12%	-
You have worked in an agricultural (non-farm) related job	16%	-
You currently work in an agricultural (non-farm) related job	9%	-

CHAPTER 3

METHODS

The central focus of this paper is to evaluate the impact of a treatment effect on respondent's attitudes concerning greenhouse operations using LED lighting in food production. To assess the treatment effect on the change in attitudes, a tobit model is used. The attitude data is censored at two extremes, 0 and 100. Ordinary least squares estimation (OLS) results in biased and inconsistent parameter estimates due to this censoring. The two-limit Tobit model developed by Rossett and Nelson (1975) is used to account for censoring of the data. The model can be represented as:

$$y_i^* = \beta' x_i + \varepsilon_i \quad (i = 1, \ldots, n)$$

$$y_i = \begin{cases} 0 & if\ y_i^* \leq 0 \\ y_i^* & if\ 0 < y_i^* < 100 \quad (i = 1, \ldots, n) \\ 100 & if\ y_i^* \geq 100 \end{cases}$$

where y_i^* is a latent variable that is not observed for values below 0 and above 100, x is a matrix of explanatory variables, β is a vector of coefficients, and ε_i is an independently and normally distributed error term with zero mean and variance σ^2. We can maximize the likelihood function in the following equation to obtain coefficient estimates as noted by Davidson and McKinnon (1993).

$$\sum_{y_t^L \leq y_t^* \leq y_t^U} \log\left\{\frac{1}{\sigma} \emptyset \left[\frac{1}{\sigma}(y_t - x_t\beta)\right]\right\} + \sum_{y_t^* \leq y_t^L} \log\left\{\emptyset \left[\frac{1}{\sigma}(y_t^L - x_t\beta)\right]\right\}$$

$$+ \sum_{y_t^* \leq y_t^L} \log\left\{\emptyset \left[-\frac{1}{\sigma}(y_t^U - x_t\beta)\right]\right\}$$

However, the estimated coefficients (β) are not interpreted in the same manner as OLS estimates (the ceteris paribus effect of a one-unit change in our independent variable on the dependent variable) (Gould et al., 1989). An extension of the McDonald and Moffitt decomposition for two-limit censoring to obtain the unconditional and conditional marginal effects and the corresponding probabilities of being uncensored (McDonald and Moffitt, 1980) is used. Unconditional marginal effects account for individuals with preferences outside of the bounds constructed by the survey. In our data, it is difficult to imagine a logical realization of preferences below 0 (should never be allowed) or above 100 (should always be allowed) to indicate the respondent's preference regarding the use of LED lighting in food production. Therefore, conditional marginal effects from the two-limit Tobit model are reported.

To assess regulation preferences, a series of tables are presented to show how respondents' preferences for regulation as well as regulating entities changed after the treatment effect. A table is presented showing the percent of respondents choosing every combination of initial and post-treatment preferences. A series of change tables are also presented that show changes in preferences for regulating entities based on respondents' regulation preferences before and after treatment. These tables allow for a unique analysis of not only changes in total percent of respondents choosing each level of regulation before and after treatment, but also how the post-treatment movement in regulation preferences relate to changes in preferences of regulating entities after treatment. Organizing the data in such a way gives us insights into the relationship between changes in an individual's regulation preferences and their preferences for regulating entities.

CHAPTER 4

RESULTS

Prior to treatment, 8% of respondents believed supplemental lighting technologies for food should not be regulated, while 21% of respondents selected “I do not know”. The most popular regulation preference prior to treatment was “regulate the same amount,” capturing 36% of respondents. Also prior to treatment, most respondents (54%) believed that state government should be responsible for regulating supplemental lighting technologies for growing food. The second most popular candidate for regulation of supplemental lighting technologies for food was the city/municipal government.

After treatment, the most popular regulation preference switched to “regulate more.” After treatment, 36 percent of respondents chose “regulate more.” “Regulate the same amount” and “I do not know” lost 4% and 7% of respondents, respectively. Overall, post-treatment preferences for regulating entities did not change much, with State government remaining the most popular candidate. See Tables 2-10 for an overview of respondents’ answers regarding prior background knowledge, concerns, and opinions regarding supplemental lighting technologies before and after treatment.

Table 2. Percent of respondents who had heard of supplemental lighting systems	%
LED	67
HPS	33
Other	23

Table 3. Distance from respondents’ primary residence to nearest greenhouse	%
5 miles or less	24

6 to 20 miles	17
Greater than 20 miles	13
I do not know	46

Table 4. Level of concern about different colors of LED lights	Mean	Std. Dev.
Red	53	27
Blue or Violet	52	27
White	50	28
Yellow	51	27
Orange	52	27
Other LED colors	51	27

Note: A response of 0 indicates “extremely unconcerned”, while a response of 100 indicates “extremely concerned.”

Table 5. Perceptions regarding safety of LED lights used in greenhouses	Mean	Std. Dev.
Safe for plants	68	25
Safe for humans during production	66	25
Safe for humans when consuming produce grown with LED lights	67	25
Safe for animals living around the greenhouse	63	26

Note: A response of 0 indicates “not safe” while a response of 100 indicates “extremely safe.”

Table 6. Opinions regarding use of supplemental lighting in food production	Mean	Std. Dev.
LED lighting	64	25
HPS lighting	58	26
Other	63	25

Note: An answer of 0 indicates “should never be allowed” while an answer of 100 indicates “should always be allowed.”

Table 7. Preferences for regulation of supplemental lighting in food production before treatment	%
Do not regulate	8
Regulate less	10
Regulate the same amount	36
Regulate more	25
I do not know	21
Mean attitude regarding whether it should be allowed	64

Note: An answer of 0 indicates “should never be allowed”, while an answer of 100 indicates “should always be allowed.”

Table 8. Preferences for regulators of supplemental lighting in food production before treatment	%
City/Municipal government	37
County government	27
State government	54
Federal government	25

Note: Respondents were able to choose more than one entity.

Table 9. Preferences for regulation of supplemental lighting in food production after treatment	%
Do not regulate	8
Regulate less	10
Regulate the same amount	32
Regulate more	36
I do not know	14
Mean attitude regarding whether it should be allowed	54

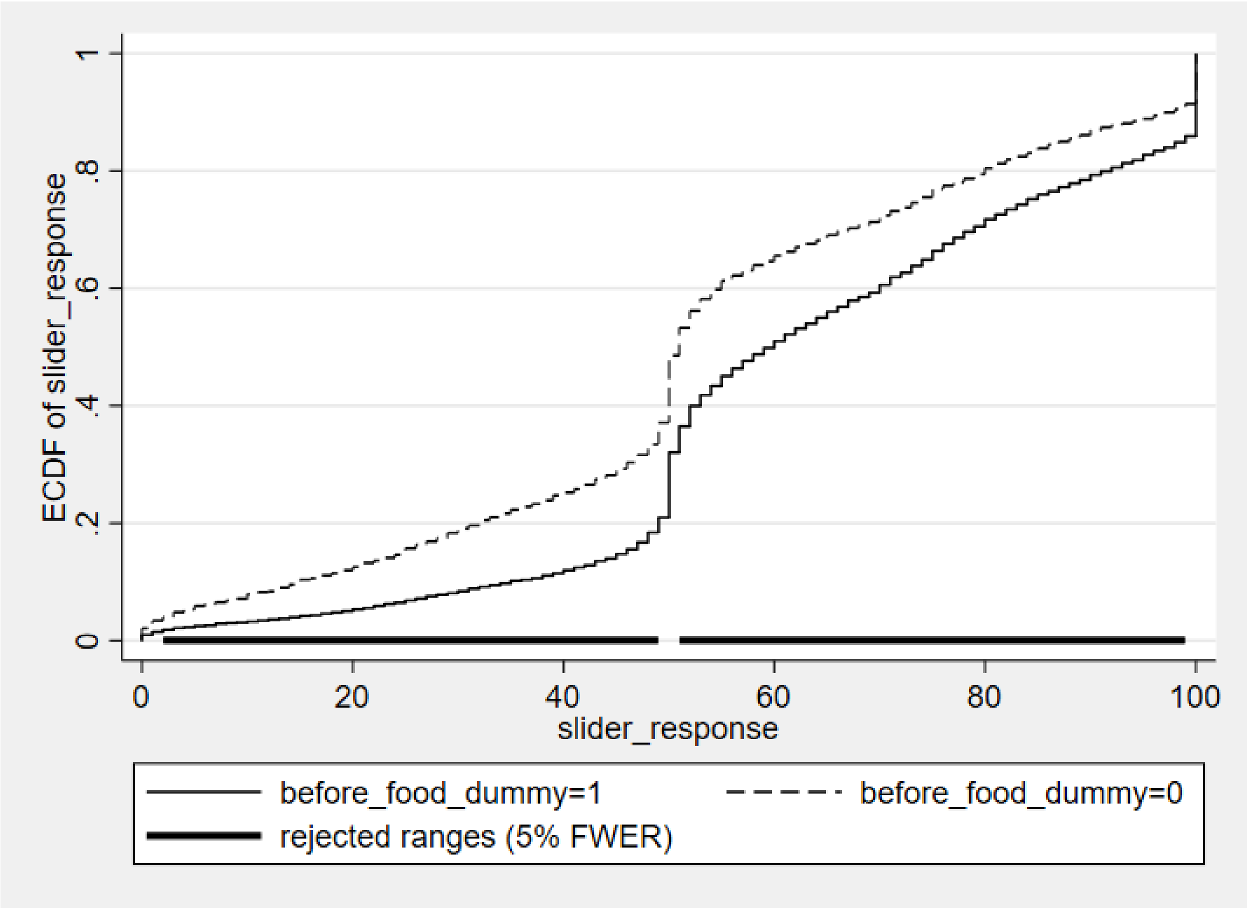
Note: An answer of 0 indicates "should never be allowed", while an answer of 100 indicates "should always be allowed."

Table 10. Preferences for regulators of supplemental lighting in food production after treatment	%
City/Municipal government	38
County government	29
State government	55
Federal government	26

Note: Respondents were able to choose more than one entity.

Figure 1 presents two CDFs of responses indicating respondents' attitudes about greenhouse producers using supplemental LED lighting before and after treatment. These CDFs suggest that there are different levels of attitude change about LED use at different points of initial attitude levels. In particular, more change may have occurred around initial levels of 40 and 60 compared to values near the extremes (e.g., 20 and 80). The CDFs are statistically different at all points except the midpoint. This provides evidence for a nonlinear effect of the initial attitude about LEDs on the post-treatment outcome of attitudes about LEDs. Therefore, it is important to consider initial regulation preferences when discussing the treatment effect of the media images on regulation preferences.

Figure 1. Before and After CDFs of Respondents' Attitudes About Supplemental LED Lighting



Tobit Model

The conditional average marginal effects from the Tobit model are presented in Table 11.[2] The unconditional effects and probabilities add little insight to the focus of our study and are therefore not provided.

[2] Tobit model parameter estimates are provided in (Appendix D) but not discussed as the coefficients from Tobit models are not easily interpretable.

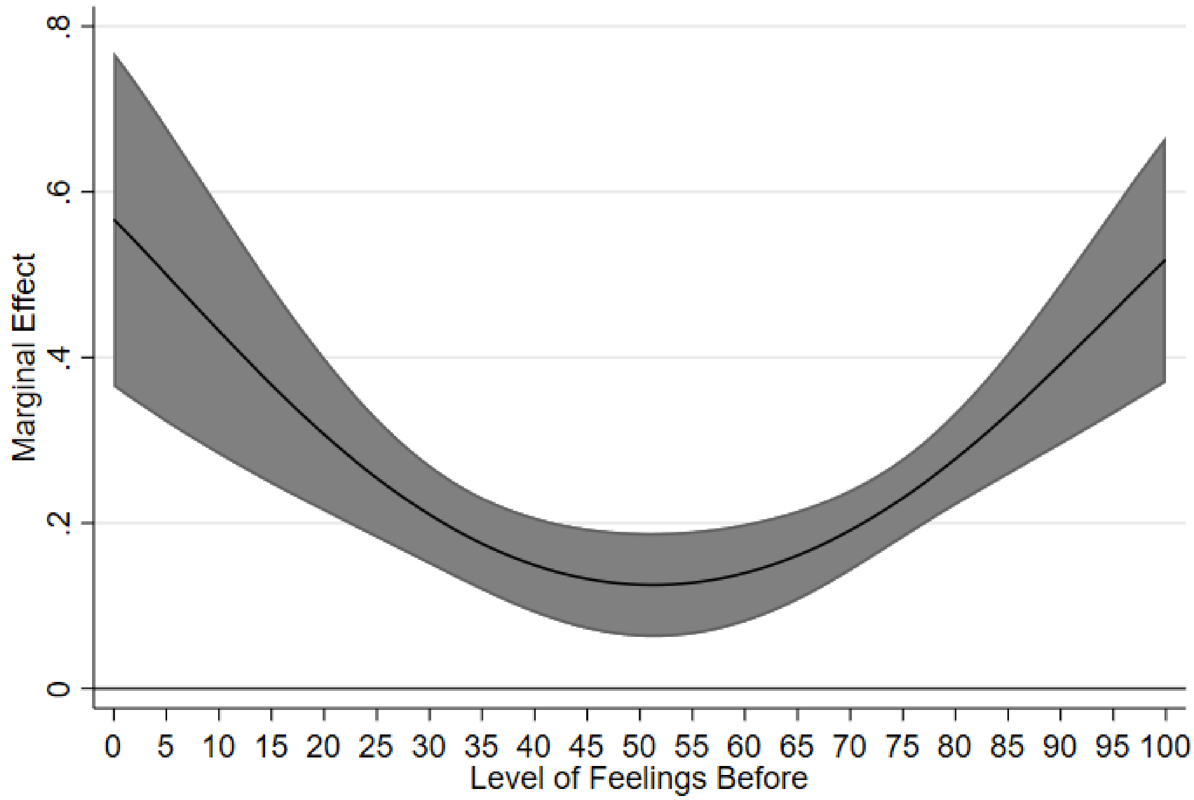
Table 11. Mean conditional marginal effects of each explanatory variable for opinions regarding use of supplemental LED lighting in greenhouses		
Variables	Coef.	P-value
Regions		
Rocky Mountains	-.2227601	0.888
Southwest	.7037503	0.512
Plains	.4337282	0.753
Great Lakes	-1.065333	0.303
Mideast	-1.049594	0.276
New England	-.3573841	0.817
Southeast	.2806353	0.757
Generation		
Gen X	**3.697783**	**0.000**
Younger	**2.596143**	**0.000**
Race		
African American	-.1285027	0.891
Other race	-1.002723	0.303
Male	**4.671245**	**0.000**
Political Affiliation		
Republican	.2034974	0.772
Other	-.9249487	0.162
Education		
High school or less	.3154418	0.730
Some college	.4015267	0.575
Greater than bachelor’s	1.126006	0.125
Number of kids in household	**.6489189**	**0.016**
Number of adults in household	.3276794	0.260
Area		
Suburban	**-1.855781**	**0.005**
Rural	**-2.02116**	**0.019**
Household income	**.0000179**	**0.017**
Primary food shopper of household	-2.062075	0.129
Primary plant shopper of household	.5710611	0.516
Distance from primary residence to nearest greenhouse		
6 to 20 miles	1.196637	0.147
Greater than 20 miles	-1.133544	0.234
I do not know	**-3.333214**	**0.000**
Index of beliefs regarding safety of LEDS used in production	**.3907084**	**0.000**
Initial regulation preference	**.2330218**	**0.000**
Note: Base categories: Regions = Far west, Generation = Older, Race = White, Political affiliation = Democrat, Education = Bachelor’s, Type of area = Metro, Distance = ≤ 5 miles.		
Bolding indicates significance at the .1 level or less.		

Gen X and Younger generations preferred less regulation after treatment relative to older generations. This could be due to the nature of younger generation's more frequent exposure to LED lighting and light from technology in general. Male survey participants selected 4.67 higher on the 0-100 scale on average. Having one or more kids in the households also results in preferences for less regulation. A $10,000 increase in household income yields an increase of .179 points on the 0-100 scale on average.

Metropolitan participants were more likely to prefer less regulation. Perhaps this is related to their more frequent exposure to ALAN than their suburban and rural counterparts. Participants with higher levels of household income tended to prefer less regulation. Interestingly, participants that did not know the distance from their primary residence to the nearest greenhouse were most likely to prefer more regulation after treatment than individuals that live 5 miles or closer to the nearest greenhouse. The increase in desire for regulation from not knowing distance to the nearest greenhouse might be explained by lack of awareness regarding agriculture or greenhouse technology or strong attitudes regarding light pollution (or both). Not surprisingly, individuals with higher initial perceptions of LED safety were less likely to prefer more regulation after treatment.

On average, the addition of a point on the 0-100 scale in the pre-treatment answer results in a .233 increase in their post treatment preference. However, this effect is nonlinear. The prior attitude response enters the Tobit model in level, quadratic, and cubic form. The level, quadratic, and cubic coefficients are significant. Figure 2 graphs the estimated marginal effect of the prior attitude across prior attitude levels. This shows that respondents at the extremes (e.g., 0 or 100) are anchored to their initial attitudes more than those in the middle (e.g., 50). This is not surprising as those with strong attitudes prior to receiving information are likely to retain those stronger attitudes. However, those without a strong opinion may be more swayed by the treatment. This provides further evidence, initially suggested by the CDFs that initial regulation preferences may play an important role in determining post-treatment regulation preferences.

Figure 2. Estimated Marginal Effect at Different Levels of Prior Attitudes



Regulation Preferences

Histograms (Figures 3 and 4) depicting preferences for regulation as well as regulators prior and post treatment give additional insight as to how treatment changed participants' opinions. "Regulate the same amount" and "I do not know" realized a 4% and 7% decrease, respectively, from before to after treatment. The 11% total decrease in those answers is reflected in the 11% increase of respondents selecting "regulate more."

The popularity of all four regulators (City/Municipal, County, State, and Federal) increased slightly, with State remaining the most popular candidate followed by County government as before. Participants were allowed to select more than one answer if they wished. No specific entity saw significant changes in the percent of total respondents selecting it as a potential regulator.

Figure 3. Preferences for Regulation Before and After Treatment

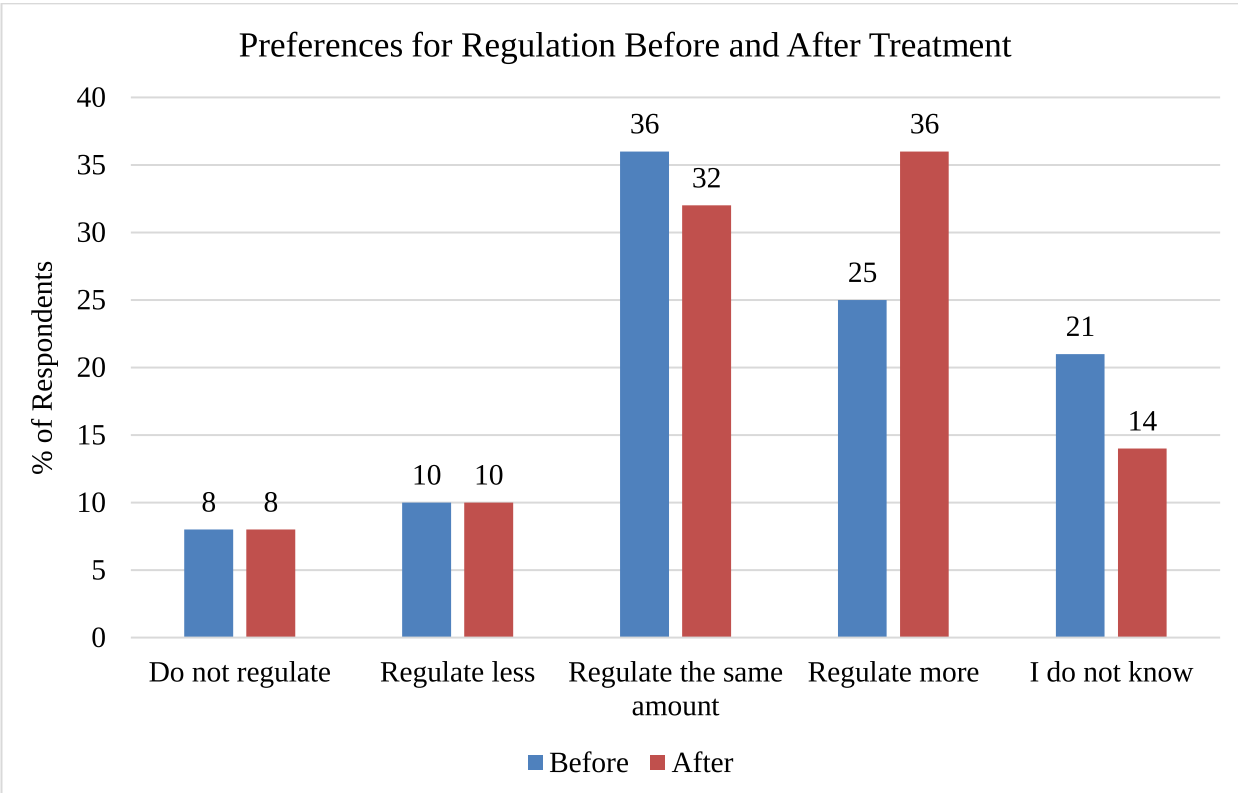


Figure 4. Preferences for Regulators Before and After Treatment

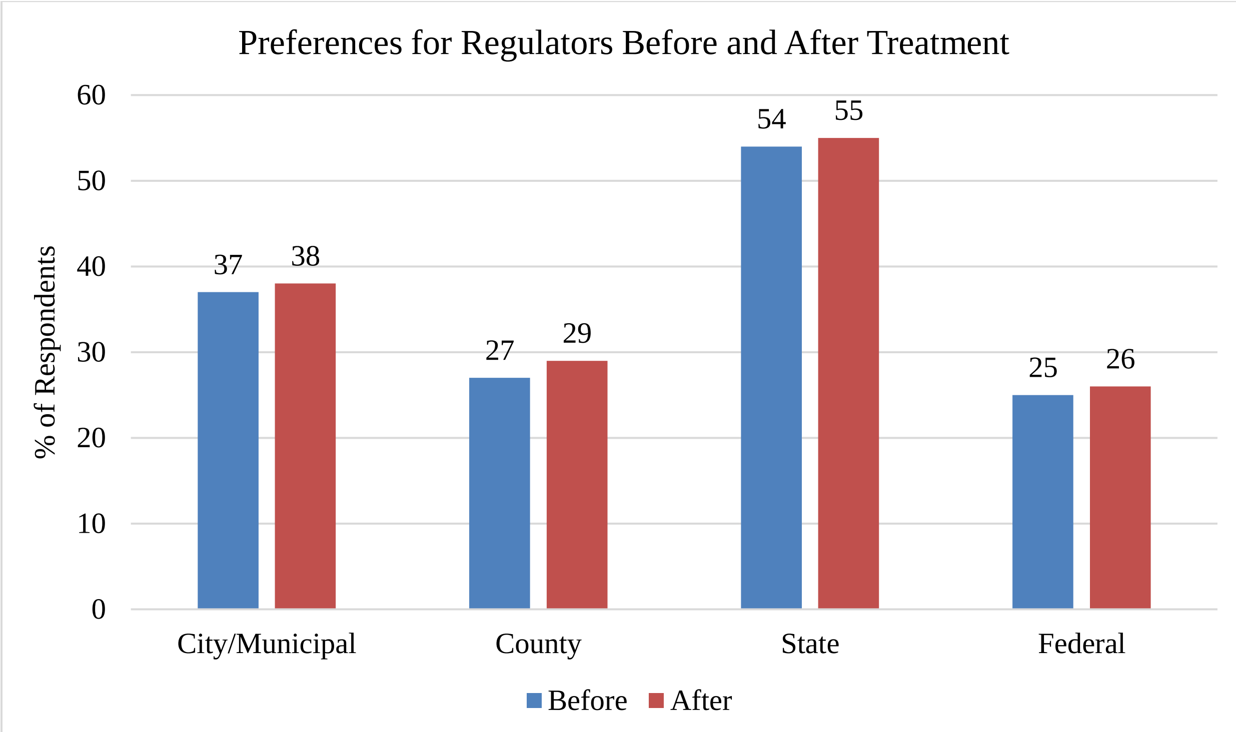


Table 12 breaks down the changes in respondents' regulatory preference amount based on their answers regarding regulation before and after treatment. In every regulation category except for "regulate less," most respondents maintained their original answer after treatment. The percentage of individuals switching to "regulate more" outweighs the percentage of individuals switching to "do not regulate" and "regulate less" in every category except for individuals that initially preferred "do not regulate." Similarly, "regulate more" is a more popular answer to switch to than "I do not know" among respondents not initially selecting "do not regulate" and "I do not know." 28% of participants choosing "regulate less" prior to treatment chose "regulate the same amount" after treatment. 16% of participants choosing "regulate less" pre-treatment chose "regulate more" after treatment. 29% of participants choosing "regulate the same amount" before treatment chose "regulate more" after treatment. 16% and 22% of individuals choosing "I do not know" prior to treatment chose "regulate the same amount" and "regulate more" after treatment, respectively.

Tables 13-17 are the change tables discussed in the last paragraph of the methods section. Table 13 shows changes in regulator preferences for individuals who preferred no regulation prior to treatment. Respondents that prefer no regulation prior to treatment are unlikely to prefer federal regulation after treatment, especially those that choose "I do not know" after treatment. The most popular post-treatment regulator in Table 13 is state government, except for individuals selecting "I do not know" after treatment. Individuals selecting "I do not know" after treatment tend to prefer city (38%) and county regulation (48%).

Table 14 shows changes in regulator preferences for individuals who preferred less regulation prior to treatment. Individuals changing regulation preference from "regulate less" prior to treatment to "regulate more" after treatment moved away from city regulation to state and federal regulation. Respondents changing their regulation preference to "I do not know" after treatment were less likely to prefer federal regulation after treatment and more likely to prefer county regulation post-treatment. Those that stayed at "regulate less" shifted slightly from state to county and federal regulation.

Table 15 shows changes in regulator preferences for individuals who preferred the same amount of regulation prior to treatment. Individuals changing their answer to "regulate less" post-treatment were less likely to choose city and more likely to choose state as a regulator than they were prior to treatment. Individuals that maintained their answer of "regulate the same amount" post-treatment were unlikely to change their answer regarding regulator preference. Overall, individuals that initially prefer "regulate the same amount" had little to no change in regulator preferences post treatment, with changes being slight increases in selection of regulators across the table.

Table 16 shows changes in regulator preferences for individuals who preferred more regulation prior to treatment. Individuals changing their regulation preference to “regulate less” post-treatment tended to want more of every regulator except for state government. Individuals remaining with “regulate more” post-treatment were more likely to prefer each regulator after treatment. Individuals changing to “I do not know” post treatment were more likely to want city and county regulation, but less likely to want regulation from the federal government. County government saw increases across the board post-treatment.

Table 17 shows changes in regulator preferences for individuals who selected “I do not know” as their regulation preference prior to treatment. Individuals changing their answer to “regulate less” after treatment were less likely to prefer city regulation, and more regulation from county and state government. Individuals changing their regulation preference to “regulate the same amount” after treatment were more likely to want involvement from city and county government and less likely to want involvement from state government than prior to treatment. Individuals changing their answer to “regulate more” were more likely to prefer participation in regulation from both state and federal government. Individuals that still had unknown regulation preferences saw a large increase in desire for county government regulation, with little changes in preferences for other regulators.

There are also changes that all or most tables seem to have in common. Individuals that want more regulation after treatment tend to want regulation by federal government more than individuals that choose “regulate less” after treatment. Individuals that choose “I do not know” before treatment seem to have inconsistent changes before and after treatment. This seems to provide some evidence that regulation attitudes and regulator preferences being separate preferences. Individuals that choose “I do not know” also seem to have some of the most extreme changes across the tables, but many of their preference changes appear similar in magnitude to other preference groups. State is always the most popular regulator among individual’s choosing “regulate more” after treatment. Interestingly, state is also the most popular regulator among individuals choosing “regulate less” after treatment. This provides more evidence that strength of attitude towards regulation and regulator preference may be independent of each other.

Table 12. Percent of Respondents by regulation preferences before and after treatment

Before / After	Do not regulate	Regulate less	Regulate the same amount	Regulate more	I do not know
Do not regulate	57%	7%	3%	1%	3%
Regulate less	14%	46%	7%	5%	3%
Same amount	12%	28%	58%	17%	16%
Regulate more	9%	16%	29%	75%	22%
I do not know	9%	4%	3%	2%	56%

Table 13. Respondents that preferred no regulation before treatment

Regulator	City	County	State	Federal
Post				
Do not regulate	0% → 0%	0% → 0%	0% → 0%	0% → 0%
Regulate less	0% → 39%	0% → 39%	0% → 41%	0% → 17%
Same amount	0% → 43%	0% → 30%	0% → 43%	0% → 10%
Regulate more	0% → 33%	0% → 27%	0% → 57%	0% → 13%
I do not know	0% → 38%	0% → 48%	0% → 34%	0% → 7%

Table 14. Respondents that preferred less regulation before treatment

Regulator	City	County	State	Federal
Post				
Do not regulate	27% → 0%	23% → 0%	46% → 0%	19% → 0%
Regulate less	41% → 40%	23% → 27%	51% → 47%	9% → 12%
Same amount	41% → 42%	17% → 19%	48% → 48%	13% → 17%
Regulate more	44% → 34%	23% → 23%	40% → 48%	15% → 23%

I do not know	43% → 43%	36% → 43%	36% → 36%	14% → 7%

Table 15. Respondents that preferred same regulation before treatment

Regulator	City	County	State	Federal
Post				
Do not regulate	48% → 0%	17% → 0%	33% → 0%	17% → 0%
Regulate less	43% → 37%	20% → 20%	41% → 52%	17% → 17%
Same amount	33% → 34%	25% → 25%	54% → 55%	23% → 24%
Regulate more	39% → 40%	31% → 32%	56% → 57%	26% → 30%
I do not know	37% → 39%	28% → 28%	33% → 33%	24% → 26%

Table 16. Respondents that preferred more regulation before treatment

Regulator	City	County	State	Federal
Post				
Do not regulate	27% → 0%	0% → 0%	73% → 0%	18% → 0%
Regulate less	41% → 47%	27% → 33%	65% → 55%	22% → 27%
Same amount	41% → 38%	27% → 29%	49% → 56%	23% → 19%
Regulate more	41% → 43%	30% → 33%	61% → 63%	31% → 34%
I do not know	25% → 40%	20% → 25%	50% → 50%	40% → 35%

Table 17. Respondents with unknown regulation preference before treatment

Regulator	City	County	State	Federal
Post				
Do not regulate	48% → 0%	12% → 0%	40% → 0%	28% → 0%
Regulate less	41% → 26%	30% → 44%	41% → 56%	11% → 11%
Same amount	30% → 35%	18% → 22%	56% → 52%	25% → 24%
Regulate more	34% → 35%	37% → 36%	56% → 62%	31% → 39%
I do not know	32% → 33%	27% → 50%	51% → 50%	28% → 28%

CHAPTER 5

CONCLUSIONS

Supplemental lighting systems will continue to grow in popularity among producers in the greenhouse and CEA industries as a strong solution to increase profit and production levels. LED systems are especially likely to be adopted at increasing rates in the future because of the energy efficiency and low maintenance costs which coincide with global efforts to reduce energy usage and therefore carbon emissions (Khanh, 2015). Keeping this in mind, it is important to understand how consumer preferences and desires for regulation change when they (or their property) are exposed to the light from LED systems directly or through the media. In addition, it is important to understand which individual characteristics have significant effects on preferences for regulation. The authors hope conclusions drawn regarding which factors most heavily influence changes in consumer preferences after treatment can be helpful to producers and policymakers.

There are multiple significant factors that influence citizens' change in preferences for regulation of LED systems in greenhouses after seeing images of light pollution from such sources. Our results show that urban areas and younger generations are less likely to want regulation after seeing light pollution caused by supplemental lighting systems. Individuals who are unaware of their primary residence's distance to the nearest greenhouse were much more likely to be opposed to lighting systems after treatment. In the case of this study, individuals unaware of the distance from their primary residence to the nearest greenhouse comprised 46% of our sample. If the goal of investors and food producers is to minimize potential conflict from the use of supplemental LED lighting in greenhouses, it may be beneficial to avoid implementation of systems in the following areas: suburban or rural areas, areas with relatively high percentages of older individuals (45+), and areas with little agriculture or ALAN already established, assuming correlation between lack of awareness of distance to nearest greenhouses and amount of agricultural enterprises already established in the area. In addition, the higher the perceptions of safety of supplemental LED systems, the less likely citizens are to prefer more regulation post treatment. It may be beneficial for producers and policymakers in key areas where greenhouse production is a significant source of cash flow and food to make efforts to educate consumers about the safety of LED lights and their benefits.

Initial attitudes and preferences play an important role in setting regulatory preference after treatment. Notably, the impact of the treatment images is different depending on initial preferences. The results suggest that those with less definitive initial attitudes will change their attitudes more than those with stronger opinions. Future research can explore the nature of different initial preferences on post-treatment outcomes for preferences of regulation of LED supplemental lighting systems beyond the aggregate effect. Such an understanding would allow for better decision and policy making based on how citizens' current preferences for regulation of LED lighting.

Of course, there are limitations to this study. While the sample is representative of the United States and may be useful in generalizing regarding consumers living in areas with demographics like our sample, it may not be representative or useful in generalizing areas with demographic characteristics significantly different than those of our sample or the United States. In addition, while the treatment of media images provides significant insight as to how citizens will react to ALAN, true reactions, and changes in preferences for LED lighting regulation may be less or more extreme when in real-world scenarios. It is possible that true changes in preferences for regulations after being exposure of citizens to light pollution are understated in this study. Policymakers and producers should take this into account when making decisions using this study.

REFERENCES

"Age and Sex Composition in the United States: 2019." *The United States Census Bureau*, 29 Apr. 2020, www.census.gov/data/tables/2019/demo/age-and-sex/2019-age-sex-composition.html.

Benke, Kurt, and Bruce Tomkins. "Future Food-Production Systems: Vertical Farming and Controlled-Environment Agriculture." *Sustainability: Science, Practice and Policy*, vol. 13, no. 1, 24 May 2017, pp. 13–26., doi:10.1080/15487733.2017.1394054.

Bessho, Makoto, and Keiichi Shimizu. "Latest Trends in LED Lighting." *Electronics and Communications in Japan*, vol. 95, no. 1, 21 Dec. 2011, pp. 1–7., doi:10.1002/ecj.10394.

Bula, R.J., et al. "Light-Emitting Diodes as a Radiation Source for Plants." *HortScience*, vol. 26, no. 2, 1991, pp. 203–205., doi:10.21273/hortsci.26.2.203.

Choi, Hyo Gil, et al. "Effects of LED Light on the Production of Strawberry during Cultivation in a Plastic Greenhouse and in a Growth Chamber." *Scientia Horticulturae*, vol. 189, 25 June 2015, pp. 22–31., doi:10.1016/j.scienta.2015.03.022.

Davidson, Russell, and James G. MacKinnon. *Estimation and Inference in Econometrics*. Oxford Univ. Press, 1993.

Dominoni, Davide M. "The Effects of Light Pollution on Biological Rhythms of Birds: an Integrated, Mechanistic Perspective." *Journal of Ornithology*, vol. 156, no. S1, 29 Apr. 2015, pp. 409–418., doi:10.1007/s10336-015-1196-3.

Dominoni, Davide M., et al. "Long-Term Effects of Chronic Light Pollution on Seasonal Functions of European Blackbirds (Turdus Merula)." *PLoS ONE*, vol. 8, no. 12, 20 Dec. 2013, doi:10.1371/journal.pone.0085069.

Falchi, Fabio, et al. "The New World Atlas of Artificial Night Sky Brightness." *Science Advances*, vol. 2, no. 6, 10 June 2016, doi:10.1126/sciadv.1600377.

Fedoroff, Nina V. "Food in a Future of 10 Billion." *Agriculture & Food Security*, vol. 4, no. 1, 21 Aug. 2015, doi:10.1186/s40066-015-0031-7.

Gould, Brian W., et al. "Conservation Tillage: The Role of Farm and Operator Characteristics and the Perception of Soil Erosion." *Land Economics*, vol. 65, no. 2, 1989, p. 167., doi:10.2307/3146791.

Hansen, Johnni, and Richard G. Stevens. “Case–Control Study of Shift-Work and Breast Cancer Risk in Danish Nurses: Impact of Shift Systems.” *European Journal of Cancer*, vol. 48, no. 11, July 2012, pp. 1722–1729., doi:10.1016/j.ejca.2011.07.005.

Khanh, Tran Quoc. *LED Lighting: Technology and Perception*. Wiley-VCH, 2015.

Kopsell, Dean A., et al. “Blue Wavelengths from LED Lighting Increase Nutritionally Important Metabolites in Specialty Crops.” *HortScience*, vol. 50, no. 9, Sept. 2015, pp. 1285–1288., doi:10.21273/hortsci.50.9.1285.

Kowalczyk, Katarzyna, et al. “Comparison of Selected Costs in Greenhouse Cucumber Production with LED and HPS Supplemental Assimilation Lighting.” *Agronomy*, vol. 10, no. 9, 2020, p. 1342., doi:10.3390/agronomy10091342.

Li, Qian, and Chieri Kubota. “Effects of Supplemental Light Quality on Growth and Phytochemicals of Baby Leaf Lettuce.” *Environmental and Experimental Botany*, vol. 67, no. 1, Nov. 2009, pp. 59–64., doi:10.1016/j.envexpbot.2009.06.011.

Lin, Kuan-Hung, et al. “The Effects of Red, Blue, and White Light-Emitting Diodes on the Growth, Development, and Edible Quality of Hydroponically Grown Lettuce (Lactuca Sativa L. Var. Capitata).” *Scientia Horticulturae*, vol. 150, 4 Feb. 2013, pp. 86–91., doi:10.1016/j.scienta.2012.10.002.

Massa, Gioia D., et al. “Plant Productivity in Response to LED Lighting.” *HortScience*, vol. 43, no. 7, 2008, pp. 1951–1956., doi:10.21273/hortsci.43.7.1951.

McDonald, John F., and Robert A. Moffitt. “The Uses of Tobit Analysis.” *The Review of Economics and Statistics*, vol. 62, no. 2, 1980, p. 318., doi:10.2307/1924766.

Mitchell, C. A., et al. “LEDs: The Future of Greenhouse Lighting!” *Chronica Horticulturae*, vol. 52, no. 1, 2012, pp. 6–12.

Morrow, Robert C. “LED Lighting in Horticulture.” *HortScience*, vol. 43, no. 7, Dec. 2008, pp. 1947–1950., doi:10.21273/hortsci.43.7.1947.

Nelson, Jacob A., and Bruce Bugbee. “Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures.” *PLoS ONE*, vol. 9, no. 6, 2014, doi:10.1371/journal.pone.0099010.

“North America's Greenhouse Capital Passes Light Abatement by-Law.” *Greenhouse Canada*, Annex Business Media, 19 Dec. 2020, www.greenhousecanada.com/north-americas-greenhouse-capital-passes-light-abatement-by-law/#:~:text=The%20provision%20on%20sidewalls%20and,lights%20between%208pm%20and%202am.

O'Donnell, Author: Bernie. “Peach Co. Man Sues Pure Flavor, County over Greenhouse Lights.” *WMAZ*, 5 Mar. 2019, www.13wmaz.com/article/news/local/peach-crawford/peach-co-man-sues-pure-flavor-county-over-greenhouse-lights/93-e6c4c49c-ba56-4792-a037-be2d9d018987.

Olle, Margit, and Akvile Viršile. “The Effects of Light-Emitting Diode Lighting on Greenhouse Plant Growth and Quality.” *Agricultural and Food Science*, vol. 22, no. 2, 26 June 2013, pp. 223–234., doi:10.23986/afsci.7897.

Rosett, Richard N., and Forrest D. Nelson. “Estimation of the Two-Limit Probit Regression Model.” *Econometrica*, vol. 43, no. 1, 1975, p. 141., doi:10.2307/1913419.

Singh, Devesh, et al. “LEDs for Energy Efficient Greenhouse Lighting.” *Renewable and Sustainable Energy Reviews*, vol. 49, 2015, pp. 139–147., doi:10.1016/j.rser.2015.04.117.

U.S. Census Bureau QuickFacts: United States. www.census.gov/quickfacts/fact/table/US/PST045219.

APPENDICES

Appendix A

Q319 Do you know how the nearest greenhouse to you provides light to its crops?

- ☐ Sunlight (1)
- ☐ LED lighting (5)
- ☐ HPS lighting (6)
- ☐ Other (7)
- ☐ I do not know (8)

Q804 Have you ever heard of the following types of supplemental lighting systems used in greenhouses?

	No (1)	Yes (2)
LED (1)	○	○
High Pressure Sodium (HPS) (2)	○	○
Other (3)	○	○

Q377 Do you think growing plants with LED lights is....

	Not Safe 0	Somewhat Safe 50	Extremely Safe 100
Safe for plants? ()			
Safe for humans during production? ()			
Safe for humans when consuming produce grown using LED lights? ()			
Safe for humans planting plants grown using LED lights? ()			
Safe for animals living around the greenhouse? ()			

Q805 Which of the following do you think are advantages of using LED lighting in a greenhouse? (check all that apply)

- ☐ Better energy efficiency than other supplemental lights (1)
- ☐ Fewer greenhouse emissions (2)
- ☐ Change bulbs less often (3)
- ☐ Do not contain mercury in the lights (4)
- ☐ Do not contain copper in the lights (5)
- ☐ Do not contain lead in the lights (6)
- ☐ Do not contain nickel in the lights (7)
- ☐ Allows for year-round production (8)
- ☐ Other (9) ____
- ☐ I do not know (10)

Q650 LED lights come in different ss, how concerned would you be about living near a greenhouse producer that uses the following colors of lights?

	Extremely Unconcerned	Neither Unconcerned/Concerned	Extremely Concerned
	0	50	100
Red LED lights ()			
Blue or violet LED lights ()			
White LED lights ()			
Yellow LED lights ()			
Orange LED lights ()			
Other LED light colors ()			

Appendix B

Q657 how do you feel about greenhouse operations using supplemental lighting in their production?

	Should never be allowed	Should be allowed in some cases	Should always be allowed
	0	50	100
LED lighting in food production (e.g., tomatoes, cucumbers, etc.) ()			
HPS lighting in food production (e.g., tomatoes, cucumbers) ()			
LED lighting in plant production (e.g., for your house or landscape.) ()			
HPS lighting in plant production (e.g., for your house or landscape) ()			
Other lighting in food production (e.g., tomatoes, cucumbers) ()			
Other lighting in plant production (e.g., for your house or landscape) ()			

Q828 Should there be regulations on using supplemental lighting technologies for growing plants for food (e.g., tomatoes, cucumbers, etc.) in greenhouses?

- ○ Do not regulate (1)
- ○ Regulate less (2)
- ○ Regulate the same amount (3)
- ○ Regulate more (4)
- ○ I do not know (5)

Q834 Who should be responsible for regulating supplemental lighting technologies for growing plants for food (e.g., tomatoes, cucumbers, etc.) in greenhouses? (Select all that apply)

- ☐ City/Municipal government (1)
- ☐ County government (2)
- ☐ State government (3)
- ☐ Federal government (4)

Q655 After seeing the pictures from media outlets above, how do you feel about greenhouse operations using supplemental LED lighting in their production?

	Should never be allowed	Should be allowed in some cases	Should always be allowed
	0	50	100
LED lighting in food production (e.g., tomatoes, cucumbers, etc.) ()			
LED lighting in plant production (e.g., for your house or landscape.) ()			

Q832 Should there be regulations on using supplemental lighting technologies for growing plants for food (e.g., tomatoes, cucumbers, etc.) in greenhouses?

- Do not regulate (1)
- Regulate less (2)
- Regulate the same amount (3)
- Regulate more (4)
- I do not know (5)

Q836 Who should be responsible for regulating supplemental lighting technologies for growing plants for food (e.g., tomatoes, cucumbers, etc.) in greenhouses? (Select all that apply)

- City/Municipal government (1)
- County government (2)
- State government (3)
- Federal government (4)

Appendix C

Q654

The following pictures come from various media outlets where supplemental LED lighting has caused concern in some neighborhoods. After looking at the pictures, please answer the question below.

Appendix D

Tobit Model Parameter Estimates		
Variables	Coef.	P-value
Regions		
Rocky Mountains	-.2988985	0.888
Southwest	.9442891	0.512
Plains	.5819747	0.753
Great Lakes	-1.429459	0.303
Mideast	-1.408341	0.276
New England	-.4795365	0.817
Southeast	.3765553	0.757
Generation		
Gen X	**4.961669**	**0.000**
Younger	**3.483493**	**0.000**
Race		
African American	-.1724243	0.891
Other race	-1.345449	0.303
Male	**6.267857**	**0.000**
Political Affiliation		
Republican	.2730519	0.772
Other	-1.241092	0.162
Education		
High school or less	.4232585	0.730
Some college	.5387667	0.575
Greater than bachelor's	1.51087	0.125
Number of kids in household	**.8707166**	**0.016**
Number of adults in household	.4396788	0.260
Area		
Suburban	**-2.490079**	**0.005**
Rural	**-2.711983**	**0.019**
Household income	**.000024**	**0.017**
Primary food shopper of household	-2.766883	0.129
Primary plant shopper of household	.7662473	0.516
Distance from primary residence to nearest greenhouse		
6 to 20 miles	1.605642	0.147
Greater than 20 miles	-1.520984	0.234
I do not know	**-4.472492**	**0.000**
Index of beliefs regarding safety of LEDS used in production	**.5242509**	**0.000**
Initial regulation preference	**.7783987**	**0.000**
Initial regulation preference quadratic	**-.0121559**	**0.000**
Initial regulation preference cubic	**.0000792**	**0.000**
Constant	-4.854682	0.185

Note: Base categories: Regions = Far west, Generation = Older, Race = White, Political affiliation = Democrat, Education = Bachelor's, Type of area = Metro, Distance = ≤ 5 miles.