011-0794
Beliefs on Climate Change and the Impact on Firms' Operations

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POMS 20th Annual Conference
Orlando, Florida U.S.A.
May 1 to May 4, 2009

Abstract

Environmental sustainability is affecting every aspect of consumers and the products they purchase. This is a key driver to how companies *operate* more sustainably to provide products and services to their customers. Further, climate change as a key variable in decisions regarding sustainability, will affect future choices. A study was undertaken to learn more about individual consumers' beliefs and attitudes about energy and global warming or climate change, energy and America's future, and the environment. It also gathered information about consumers' willingness to pay for cellulosic ethanol in the form of E85 as an alternative to gasoline. Initial statistical analysis has been conducted, including linear regression. Additional theoretical frameworks and models will be presented in this paper to expand upon the initial analysis to assist decision makers to make better informed decision. Funding for this research was provided by NSF and the USDA.

Introduction

There are a number of ways in which a product can be introduced into the market. The two main strategies are market pull and technology push. Each of these strategies will have an impact on the willingness of consumers to purchase and pay for the product or service. Beliefs and knowledge about energy, global warming, and climate change are important variables in understanding the cultural models that support mitigation. A study of residents in Minnesota, Wisconsin, and Michigan was undertaken to learn more about their climate change beliefs and how they would impact support for energy-related mitigation strategies (biofuel, energy tax, and conservation). A literature review was completed to identify prior studies completed addressing these specific issues. Questions for the survey were drawn from interviews and prior studies (Dietz, et al, 2007; Kempton et al. 1995; Leiserowitz 2006). The survey was pretested and modified prior to sending out to residents. Residents' beliefs provide useful information as consumers and citizens related to energy-related mitigation strategies. Once the data was collected from residents, two different analytical approaches were applied to arrive at statistically significant linear regression models. However, because of the dimensionality of the data, the need was recognized to conduct further analysis to reduce the dimensionality using principal components analysis. The principal components analysis yielded interesting findings and a modification of the initial groupings. The results of the principal components analysis is provided in this study to explore how the different variables may be grouped. The work in this paper represents the initial phase of our work. It is expected to be refined after our initial exploratory analysis to reduce the dimensionality of the number of variables in the study that is presented in this paper. The next steps, which form the basis for the continuation of our research, is to finalize our dimensionality reduction and use that as a basis for developing a predictive model. Future research includes using the factor scores to arrive at a statistically significant predictive model.

Literature Review

Climate change is a complex phenomenon that has been politically charged. These two characteristics make it difficult for the citizen-consumers of a democracy to support effective solutions to this global problem. A number of studies have found Americans to be quite concerned about climate change, but unclear in their support for the most effective measures to prevent it from happening, such as energy conservation policies (Dietz, et al, 2007; Kempton et al. 1995; Leiserowitz 2006). This is likely tied to their misunderstandings of climate change causes. Kempton et al (1995) performed research with U.S. residents in the early 1990s to assess what they termed their "cultural models" of climate change causes, impacts, and solutions. They found that individuals used the cultural models they already had for understanding seemingly similar problems, like the hole in the ozone layer and classic air pollution issues, to understanding climate change. Thus people conflated climate change with ozone depletion and believed that it was being caused by industries emitting dirty pollution that could be solved with filtering technologies. They posited, but did not test out, the notion that these misunderstandings would reduce support for effective policy and market solutions to climate change. We set out to determine a) whether these early 1990's findings still held true in the U.S. in 2007 and b) if they were indeed linked to lower support for effective solutions to climate change.

The literature review resulted in the preliminary theoretical framework for the beliefs variables displayed on the left in Figure 1.

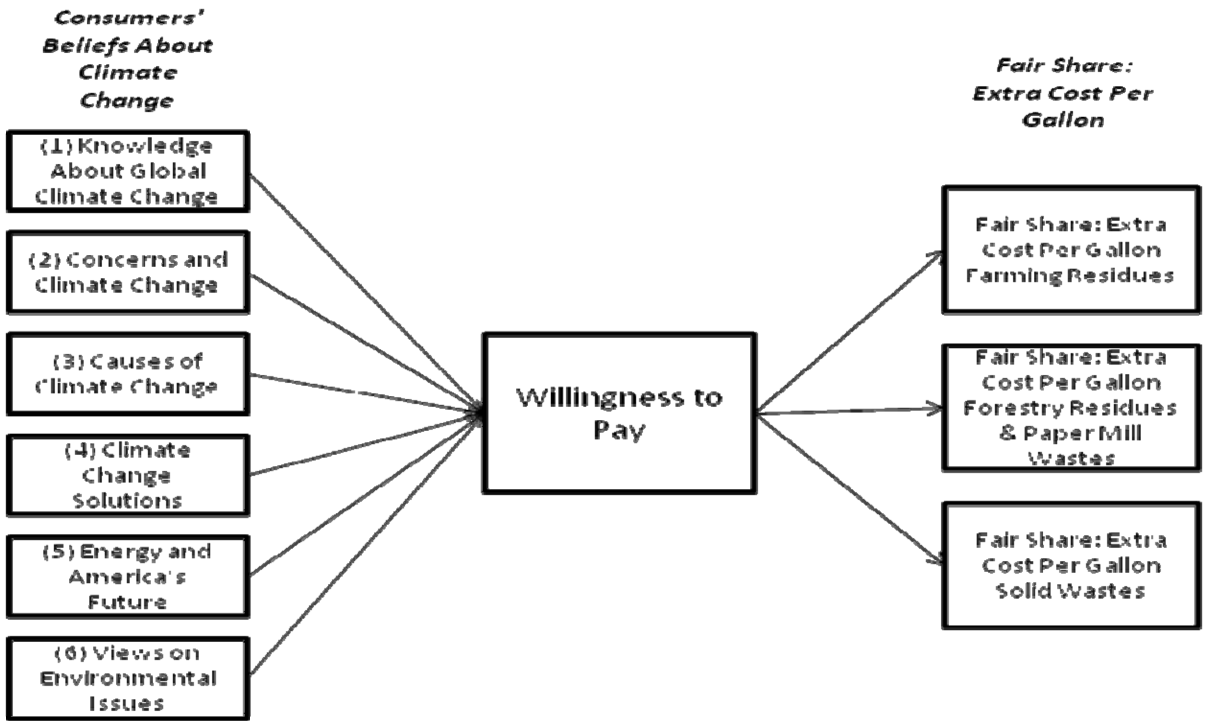

Figure 1: Theoretical Framework

Each of the questions were coded based on their inclusion in a particular categorical grouping. The numbers in the left hand boxes indicate the section in the survey. Coding for these questions is as follows: Knowledge About Global Climate Change (KAGCC), Concerns and Climate Change (CACC), Causes of Climate Change (COCC), Climate Change Solutions (CCS), Energy and America's Future (EAAF), and Views on Environmental Issues (VOEI). The coding of the primary dimensions will be important as the constructs (each survey question) is loaded on factors through principal components analysis.

To extend the prior analysis, the following research questions were formulated.

Research Questions

This research expands the existing analysis and models to frame the research problem in a slightly different fashion. Based on the Theoretical Framework (Figure 1), the primary research questions are:

1. Do consumers' beliefs about global climate change have an impact on their willingness to pay a fair share extra cost per gallon for cellulosic ethanol?
2. What are the major factors (attitudinal variables) that predict consumers' willingness to pay more?

Propositions

Based on the above research questions, we develop the following propositions:

P1: High self-perceived familiarity with global climate change will make consumers more likely to be willing to pay more for cellulosic ethanol.

P2: Consumers who are more concerned about climate change are more likely to pay more for cellulosic ethanol.

P3: Accurate understanding of the causes of climate change causes will make consumers more like to be willing to pay more for cellulosic ethanol.

P4: Accurate knowledge of climate change solutions will make consumers' willing to pay more for cellulosic ethanol.

P5: Consumers who value America's energy security will be more likely to be willing to pay more for cellulosic ethanol.

P6: Consumers with stronger environmental values will be more likely to be willing to pay more for cellulosic ethanol.

Methodology

Before being able to test the propositions, an intermediate step is to reduce the dimensionality of the data. Because of the large number of attitudinal variables in this study, *Principal Components Analysis*, or *PCA*, is a data analysis tool that is usually used to reduce the dimensionality (number of variables) of a large number of interrelated variables, while retaining as much of the information (variation) as possible. PCA calculates an uncorrelated set of variables (*factors* or *pc's*). These factors are ordered so that the first few retain most of the variation present in all of the original variables (Hintze, 2007).

Filling in Missing Values with Averages

There are a number of ways to address missing values. One of the approaches is to ignore the entire observation. This could severely limit the analysis by removing a large number of observations.

> "A growing number of programs offer the ability to fill in (or impute) the missing values. The naive choice is to fill in with the variable average. Number Crunching Statistical Software (NCSS) offers this option, implemented iteratively. During the first iteration, no imputation occurs. On the second, third, and additional iterations, each missing value is estimated using the mean of that variable from the previous iteration. At the end of each iteration, a new set of means is available for imputation during the next iteration. The process continues until it converges. The advantages of this method are greater efficiency (since it takes advantage of the cases in which missing values occur) and speed (since it is much faster than the EM algorithm to be presented next). The disadvantages of this method are biases (since it consistently underestimates the variances and covariances), unreliability (since simulation studies have shown it unreliable in some cases), and domination (since it is dominated by the EM algorithm, which does much better although that method requires more computations) (Hintze, 2007). "

For this analysis, we have used the iterative approach for computing means until convergence. Although it has its disadvantages, this approach was appropriate for the data set, given the number of missing variables was not significant.

Varimax Rotation

Varimax rotation is the most popular orthogonal rotation technique. In this technique, the axes are rotated to maximize the sum of the variances of the squared loadings within each column of the loadings matrix. Maximizing according to this criterion forces the loadings to be either large or small. The hope is that by rotating the factors, you will obtain new factors that are each highly correlated with only a few of the original variables. This simplifies the interpretation of the factor to a consideration of these two or three variables. Another way of stating the goal of varimax rotation is that it clusters the variables into groups; each "group" is actually a new factor. Varimax rotation was utilized in arriving at the factors from principal components analysis.

Selection of Factors

Several methods have been proposed for determining the number of factors that should be kept for further analysis. However, remember that important information about possible outliers and linear dependencies may be determined from the factors associated with the relatively small eigenvalues, so these should be investigated as well. There are a number of ways to select the factor to be included in the model. These selection techniques include (a) reviewing the eigenvalues, (b) reviewing individual and cumulative percentages of explained variation, and (c) using scree plots.

Eigenvalues

The eigenvalues of the *R-U* matrix are used to determine how many factors to retain. One rule-of-thumb is to retain those factors whose eigenvalues are greater than one. Kaiser (1960) proposed dropping factors whose eigenvalues are less than one, since these provide less information than is provided by a single variable. Jolliffe (1972) feels that Kaiser's criterion is too large. He suggests using a cutoff on the eigenvalues of 0.7 when correlation matrices are analyzed. Other authors note that if the largest eigenvalue is close to one, then holding to a cutoff of one may cause useful factors to be dropped. However, if the largest factors are several times larger than one, then those near one may be reasonably dropped. In this research, we used an eigenvalue of greater than 2.0, which resulted in five factors included in the analysis.

Individual and Cumulative Percents

Another criterion is to preset a certain percentage of the variation that must be accounted for and then keep enough factors so that this variation is achieved. Usually, however, this cutoff percentage is used as a lower limit. That is, if the designated number of factors do not account for at least 50% of the variance, then the whole analysis is aborted. In cases where there is significant variation in the data, then below the 50% explanation of variance still allows for drawing relevant conclusions about the data. The criterion of substantive importance test was to achieve a contribution to explaining variation of at least 5%. In other words, the factor needs to explain at least 5% of the variation (on the individual percent). We used the later approach.

Scree Plots

Cattell (1966) documented the *scree plot*. Studying this plot is probably the most popular method for determining the number of factors, but it is subjective, causing different people to analyze the same data with different results. However, in our work, the results of the scree plot collaborate with the other two approaches we applied and assisted in identifying factors.

Discussion of Results of Principal Components Analysis

In this case a combination of eigenvalues, individual percentages for explaining variation, and scree plot were used to determine the number of factors to retain in the model. Adding one more factor would not significantly increase the cumulative variation explained by the model. At 46.04%, it is slightly lower than the 50% typically recommended. However, in the initial data screening, it should be noted that the majority of the variables had a high level of variation as noted with standard deviations greater than 1.0. In this case, we did not use the weighted approach and this may have resulted in a lower explained variation. Table 1 shows the results of the principal components analysis, including the eigenvalues, individual percent, cumulative percent, and the scree plot. In this case all three decision criteria were aligned and improved the interpretation of results and the inclusion of factors.

No.	**Eigenvalue**	**Individual Percent**	**Cumulative Percent**	**Scree Plot**
1	5.043213	11.46	11.46	|||
2	2.592580	5.89	17.35	||
3	3.768233	8.56	25.92	||
4	2.727558	6.20	32.12	||
5	6.126558	13.92	46.04	|||

Table 1: Eigenvalues after Varimax Rotation

Factor Loadings

As a result of the principal components analysis, several different groupings emerged. The factor loadings represent the correlations between the variables and factors. These groupings have been named to reflect the variables that loaded on each factor. The original constructs were identified by coding in the earlier section. Letters a-h denote the construct within the former dimensions.

In the case where the variables loadings onto the different factors affect the groupings, some suggest that using 0.50 as the minimum correlations can result in more refined factors. In this case, had 0.50 correlation been applied, there would be less variables loaded on the factors and likely similar grouping "operational definitions" would still have emerged. Table 2 shows the factors, the variables (constructs) loaded on each factor and the operational definitions given to each factor. "Rev" denotes that a reversed question and the initial question has been restated and reversed scored to develop the model.

Factor #	**Factor Description**
Factor 1	**Causes and Mitigation of Climate Change**
COCCe	-0.7247
COCCf	-0.7236
COCCg	-0.7133
COCCh	-0.6719
COCCd	-0.6549
EAAFd	-0.6511
CCSe	-0.6409
CCSd	-0.5685
Factor 2	**Knowledge of Climate Change**
KAGCCa	-0.8592
KAGCCb	-0.8424
KAGCCc	-0.8212
Factor 3	**Control of Climate Change**
CCSa	0.7203
COCCc	0.6678
COCCb	0.6667
CCSc	0.5916
CCSb	0.5700
Factor 4	**Energy Consumption and Price**
EAAFf	-0.7361
EAAFgrev	-0.6766
CCSf	-0.6446
EAAFbrev	0.5089
EAAFhrev	0.5045
Factor 5	**Concerns and Climate Change**
CACCa	-0.7645
CACCf	-0.7499
CACCb	-0.7453
CACCg	-0.7394
CACCc	-0.7335
CACCd	-0.6703
KAGCCgrev	-0.5827
KAGCCh	-0.5469

Table 2: Factor Loadings and Factor Descriptions

Based on the factor loadings, two similar groupings emerged. Factor 2 Knowledge of Climate Change is similar to the original dimension of Knowledge About Global Climate Change (KAGCC). The second factor that was similar is Factor 5 Concerns and Climate Change, which is similar to the original dimension Concerns and Climate Change (CACC). Three new groupings emerged based on the factor loadings. These have been named Causes and Mitigation of Climate Change, Control of Climate Change, and Energy Consumption and Price. The theoretical framework (Figure 2) has been modified to reflect the results of the principal components analysis.

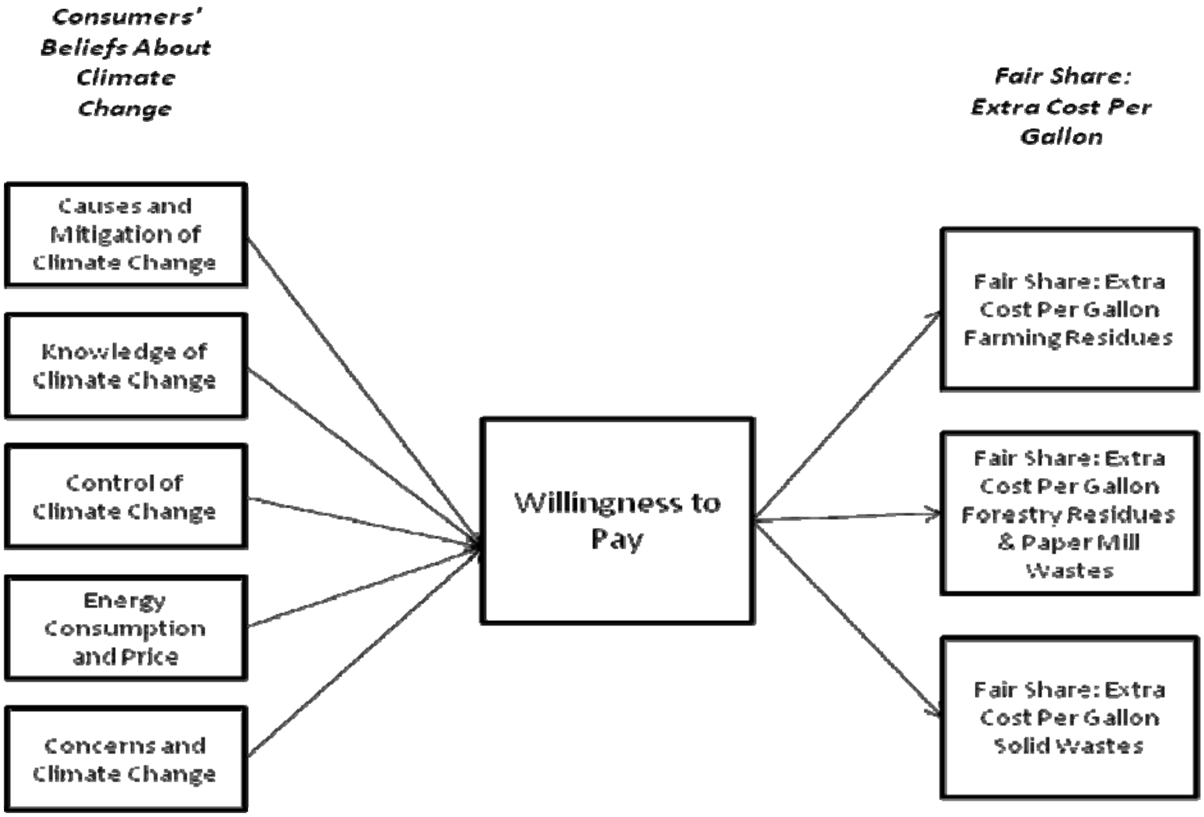

Figure 2: Revised Theoretical Framework Based on Principal Components Analysis

Conclusion

This step of the research will lead to the next phase. As a result of our findings, we will revisit the principal components analysis and use robust estimation to better reflect the variability of the data by using a weighted approach. We will also set the threshold for factor loadings at 0.50 to reduce the dimensionality even further. Once the factors are re-determined using a more refined application of principal components analysis, we will then move further by testing our propositions and learning if there are predictive models. We anticipate using a technique like robust regression where the factor scores from the principal components analysis will serve as the independent variables and the willingness to pay will serve as the dependent variables. This will allow us to draw further conclusions about the data and the predictability power that it may yield. Given the market pull versus the technology push operations strategies, it would appear that this is characteristic of technology push with the anticipation that consumers are willing to pay for mitigating the negative environmental impacts that can result from continuing growth and use of fossil fuels through higher fuel prices.

Acknowledgement

The authors would like to acknowledge the support of the National Science Foundation under grant no. BE/MUSES-0524872 to complete this research and several other papers and presentations.

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