Local Acceptance and Heterogeneous Externality of Biorefineries: A Case Study from the State of Michigan

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Abstract

While the use of biofuels can mitigate climate change, the siting and operation of a biorefinery can have both positive and negative externalities for the host community. Given these externalities, local acceptability is a key factor affecting a biorefinery location decision and the likely success of this type of mitigation investment. Numerous articles discuss the economic impact of biofuels, but there is little systematic analysis of local acceptability of biofuel production facilities. Our study explores factors that influence community attitudes towards biofuel facilities. We also assess the strength of local acceptability or opposition by estimating the local community's willingness to pay (WTP) either to support or to oppose a proposed biorefinery. We find that, conditional on the respondent's initial position, the WTPs provide a more comprehensive picture of local acceptability. County level socio-economic characteristics are found to significantly influence the attitudes as well as the WTPs.

Keywords: local acceptance; biorefinery; willingness to pay; climate change

JEL Codes: Q18 Q54

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1. Introduction

Biofuel production has grown rapidly in the US since 2007 (Renewable Fuels Association, 2015; US EIA, 2015). For the bioenergy industry, site selection is an important component of the success of a project, especially because transportation costs (for both inputs and outputs) constitute a significant portion to the cost of production. However, acceptance by the local community also plays a key role in the success of a biofuel refinery project, as a more accepting community may offer incentives that offset costs, while a less accepting community may create delays in permitting or increase project and other costs. Some studies show that opposition from the local community also decreases the probability of siting a bioenergy plant (Fortenbery et al., 2013; Haddad et al., 2009; Tigges and Noble, 2012). These studies view the opposition mainly as a not-in-my-back-yard (NIMBY) effect, when the reasons may be more nuanced.

We posit that local acceptance is a function of local welfare changes due to the proposed biorefinery project. While a biorefinery project may impose both positive and negative externalities on local communities, so long as perceived benefits exceed perceived costs, such a project is likely to be welcomed by the local community. A biofuel facility might bring benefits such as job opportunities, purchases of locally produced inputs, tax revenues, funding sources for local infrastructure, to the local community (Fletcher, 2014; Futch, 2014). To reap these benefits, local governments may offer property tax relief and other financial support to the biorefinery investors (Blackwell, 2014; Abuelsamid, 2010; Hoppe et al., 2011). On the other hand, there are also instances of communities resisting planned investments in biofuel facilities (Selfa, 2010; Stephen et al., 2010; Lambert, 2009; CTV Kitchener, 2012). Local opposition might reduce profitability (Panoutsou et al., 2013) due to project delays, lawsuits or protests from local groups, or in more extreme cases, vandalism. The opposing groups also incur costs (primarily time, but potentially out-of-pocket expenses for media campaigns or lawsuits), further reducing welfare.

Developing systematic information on community attitudes towards biofuel facilities and degree of acceptability can aid regional planners and biorefinery developers in making informed decisions and avoid potential waste of money and time for both proponents and opponents. However, there is little systematic analysis of local acceptability with regard to biofuel production (Chin et al., 2014). A straightforward approach might be to poll the residents, but a simple poll may produce information on the proportion of local residents who are supportive or against the biorefinery without indicating the strength of welfare gains/losses associated with a new facility. For example, projects that have widespread but individually small welfare losses, along with highly concentrated benefits to a minority, are likely to indicate lack of support in polls, but in reality such opposition may not produce protests and lawsuits. In contrast, substantial welfare losses to a minority may bring about vocal opposition and lawsuits.

This study aims to identify the factors that might influence local acceptability of a biorefinery by estimating the willingness to pay (WTP) either to support or oppose a biorefinery. We use WTP estimates as a measure of local acceptance since WTP originally developed as a measure of welfare changes. We assume that local acceptance is a function of welfare change.

We conduct a statewide survey including a scenario in which a proposed biorefinery would be sited in the community where the respondent lives. We adopt a two-step framework to stratify the supporters and opponents and estimate the WTPs conditional on the attitudes towards the biorefinery. The Heckman process is used to correct potential sample selection bias. The determinants of the attitudes or WTPs are informative for decision making. Finally we provide spatial analysis to show how the results can be used to map potential areas of local acceptance or opposition.

2. Literature Review

Studies on local acceptance of renewable energy facilities began appearing in the literature in the late 1990s (Roos et al. 1999). The early literature focused more on the opposition part of local acceptance, i.e. NIMBYism, but then shifted to more generic ideas about public attitudes toward such facilities, suggesting that NIMBYism is not the only factor influencing public attitudes toward proposed projects, and labeling opposition as NIMBYism may oversimplify its causes (Chin et al., 2014; Devine-Wright, 2005; Wolsink, 2007a). For instance, local opposition to wind power facilities was found to be independent of the distance between the respondent and the facilities (Wolsink, 2007b, 2000).

The terms used to describe the public attitudes of the local community towards a certain project include community acceptance (Wüstenhagen et al., 2007), local social acceptance (Breukers and Wolsink, 2007), local acceptance (Soland et al., 2013), among others. We use “local acceptance” to refer to public attitudes of the local community and “social acceptance” when the scope includes the broader society.

The acceptance of bio-energy plants from the general public, locally or not, is important (Breukers and Wolsink, 2007; McCormick, 2010), but understanding of the factors contributing to local acceptance of biorefineries or bio-energy plants is limited. Many articles discuss the acceptance of renewable energy facilities such as wind farms and solar farms, but only few analyze acceptance of biofuel production facilities. Chin et al. (2014) discuss social acceptance of biofuel development, but no quantitative analysis was conducted. Sacchelli (2014) use a

Fuzzy Cognitive Map technique to identify the factors influencing social acceptance of biomass plants from the view of bio-energy experts rather than local community. To understand local attitudes towards the biofuel facilities, Amigun et al. (2011) conducted a survey and interviews to explore the local acceptance of biodiesel production in South Africa and found the main concerns were pollution and health risks.

Similarly, among dozens of site selection articles which discuss biofuel facilities, only a few studies have taken local acceptance into consideration. For example, Tigges & Nobel (2012) qualitatively assess factors influencing biofuel facility location decisions, while Haddad et al. (2009) find an association between population density and biofuel location decisions. Fortenbery et al. (2013) used population and education to capture local acceptance in their study of biorefinery location decisions. They found that population has a positive effect on biorefinery siting while higher education level is associated with more opposition of such facilities.

Very few studies quantitatively analyze factors influencing local acceptance of biofuel facilities from the perspective of local residents. The exception is the study by Soland et al. (2013), which quantitatively explored the local acceptance of a biogas plant using a multiple choice question.

Polls or similar methods may not adequately assess the degree of support or opposition since a biofuel facility would bring various kinds of positive and negative impacts, which affect different sections of the community in different ways. As a result, the degree of opposition/support can vary significantly across members of a community, which may not be captured with a “yes/no” format, or even with a Likert scale type questions. The WTP method is an alternative to polls not only to explore the public opinions on certain policies but also to elicit the strength of such opinions (Hall et al., 2004; Joewono, 2009; Jones-Lee, 1993; Nagin et al., 2006; Walton et al., 2004). Since a WTP question involves the respondents' welfare change, Nagin et al. (2006) further argue that it is a more accurate tool than traditional polls. The WTP approach also allows decision makers to anchor the possible benefits or costs due to the biorefinery which a poll cannot. To our knowledge, no prior study has estimated public WTP for a biorefinery. Our study addresses this gap in the literature, and also offers a method that might be used for siting decisions of other types of facilities where opinions about the desirability of the facility may differ among members of potential host communities.

3. Method

Conventionally, contingent valuation methods estimating WTP assume that WTP is non-negative (Clinch and Murphy, 2001) due to the probability distributions commonly used in the likelihood functions. The simple reason for such an assumption is public goods can be ignored if they are not desired (Bohara et al., 2001; Haab and McConnell, 1998, 1997). However, public goods result in both winners (positive utility) and losers (negative utility) (Haab and McConnell, 1998; Kriström, 1997) to some degree. In the case of biorefineries, the potential for negative externalities might be higher compared to other public goods (such as a library or an emergency response system), so it is important to treat the negative side of the distribution with care in the case at hand. Further, exclusion of negative WTP in the estimation would result in biased estimates in the cases with both positive and negative externalities (Hanley et al., 2009). To deal with the negative WTP, Kriström (1997) suggested that the spike model designed for non-negative WTP can be extended using a mixture likelihood function which incorporates positive, zero, and negative utility changes into one function; Hanemann & Kanninen (1999) illustrate this idea in a more comprehensive way. Bohara et al. (2001) evaluated the performance of the mixture model by Monte Carlo simulation and found that it does not outperform the standard models if the negative WTP proportion is more than 30%. Nahuelhual-Muñoz et al. (2004) used empirical data to test if there is a difference between the estimates from the spike model and the extended spike model. They found the estimate from the extended spike model is lower than that from general (non-negative) spike model.

Alternatively, Macmillan et al. (2001) dealt with the negative WTP issue by including willingness to accept (WTA) questions to the opponents and incorporating the WTA as negative WTP bids within one regression function by either dropping the non-negative assumption or introducing two variables to represent zero and negative WTP (Macmillan et al., 2001). However, the use of a WTA framework often leads to the concern of unrealistically high numbers in the question (Arrow et al., 1993). Moreover, significant disparity between WTP and WTA estimates for the same good have been reported, especially in the case of non-market goods (Horowitz and McConnell, 2002; Zhao and Kling, 2001). This disparity could lead to biased estimates of the strength of support and the strength of opposition to a biorefinery.

One way to handle this winners and losers issue within a WTP frame work is to separate the respondents into supporters and opponents. Keith et al. (1996), in their valuation of wilderness designation, separately estimate supporters' WTP and opponents' WTP. Clinch & Murphy (2001) stratify the respondents according to their attitudes towards a forest plantation project while estimating the WTPs. They first ask the respondents' opinions regarding the effect of the forest project on the environment; then depending on their responses, the respondents are classified into two groups, welfare gainers and losers (Clinch and Murphy, 2001). Loureiro et al. (2004) also used a censoring framework in their survey design when they conducted a valuation of forest clearing burn program in Florida. Nahuelhual-Muñoz et al. (2004) used a similar framework in their questionnaire design, but they employed the extended spike model proposed by Kriström (1997). McCartney (2006) and Hanley et al. (2009) also adopted the extended spike model in their studies after they stratified the respondents according to their attitudes.

Hanley et al. (2009) argued that the scenario framework of negative WTP should take the format of reducing the good rather than preventing the increase of the good as suggested by Clinch & Murphy (2001) since, with the same amount of marginal change, the two formats elicit different measurements of welfare change. In the case of the biorefinery, however, it is not practical to design scenarios implying a reduction of the good if the question is one of build/not build. To enable an apples-to-apples comparison, we measure the strength of support (WTP to support installing a biorefinery) of the project vs. the strength of opposition (WTP to oppose installing a biorefinery).

Our study adopts a format similar to Clinch & Murphy (2001). This method supports the non-negative assumption by separating the respondents into supporters and opponents. This allows us to identify the heterogeneity in either the supporters' or the opponents' group. Furthermore, the first stage result can be analyzed as a simple poll, and that approach facilitates exploration of potential differences in conclusions based simply on percent support vis a vis conclusions based on the WTP based assessments of relative strength of support/opposition.

A single bounded dichotomous choice question is used to elicit the respondent's valuation of the biorefinery. The supporters' WTP and opponents' WTP are estimated separately using different sub-samples, and the Heckman process is used to test and correct the potential sample selection bias due to the use of sub-samples. Robust cluster variance estimator is used to correct for the potential correlation clustered at county level due to demographic factors.

4. Survey Design and Data

We implemented the WTP scenario and questions via a stratified random telephone survey of Michigan adults.[1] A total of 1,013 residents were interviewed using a standard protocol and questionnaire between January 14, 2013, and March 4, 2013. Respondent gender, race, and locality, etc. were weighted to represent the population distribution of Michigan. To capture community-level effects, we merged the survey data with county level data from USDA 2012 Agriculture Census, American Community Survey (5-Year Estimates), U.S. Geological Survey, National Climatic Data Center and National Oceanic and Atmospheric Administration.

During the telephone survey, the respondents were first asked if they support or oppose a possible biorefinery given the following scenario:

Consider the following scenario. A company is considering opening a biofuel plant in your community. They plan to buy corn and grass from nearby farmers and process it into biofuel that can be used instead of gasoline in cars. Building the plant will take one hundred million dollars, and it will employ thirty people with an average salary of sixty-five thousand dollars plus health insurance when complete.

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[1] For details of the basic survey design or to access the data, access http://ippsr.msu.edu/soss/. Refer to SOSS 64. We implemented some post-survey data treatment, as follows. Since the number of opponents was fewer than expected, we added the pretest observations into the dataset and imputed the missing data in dependent variables. Since the WTP eliciting format in pretest was open ended, to add them to the major data set, we randomly stratified the pretest observations to one of the five bid value groups in the same proportion as in the main survey. Monte Carlo simulation confirms that the significant level of the coefficient of the bid value variable, which in theory should be significant, is within 10% according to the results of a 1,000 time simulation. Some respondents did not reveal their attitudes towards the biorefinery. These were randomly assigned to either supporter group or opponent group and then were asked the second stage WTP question. Although it is possible that the respondents might have positive attitude but were assigned to the opposite group, the pretest result of open ended question shows no such situation. If they did not reveal their attitudes towards the biorefinery, these respondents just have zero value or answered “Don’t Know” or “Refuse to Answer”. The respondents who did not reveal their valuation of the biorefinery are treated as “No” response using the same logic as Caudill and Groothuis (2005) and Groothuis and Whitehead (2002). We test the potential bias resulting from the random assignment of the respondents who did not reveal attitudes. The results show that except for race, there is no support to reject the hypothesis that the mean values of the characteristics are the same between the two sub groups.

The question specified the investment and job creation numbers based on information about typical facility size supplied by industry experts. The information was provided to control for possible variations in WTP due to variations in respondent's assumptions on these parameters. The question framing mirrors the situation that the general public would face at an early stage of biorefinery siting: limited information about the proposed plan.

After the respondents stated whether they would support or oppose the biorefinery, we employed a single-bounded dichotomous choice question for eliciting the WTP conditional on the respondent's attitude. Based on pretest results, we selected a set of five bid values[2] for each group. The proportion of sample size for each stratum of the bid values was determined by the method which minimizes MSE of the estimated WTP given a total sample size (Cooper, 1993).

The supporters were asked the following WTP question where t_s is one of \$1, \$5, \$10, \$30, or \$100 bid values:

What if your local government were considering a proposal to help the company with its start-up costs as a way to attract the plant? Would you be willing to vote for a program that would cost you t_s *dollar(s) in one-time taxes to help the plant get started?*

The opponents were asked the following symmetric question to avoid bias due to asymmetric description. Here, t_s is assigned a value of \$1, \$3, \$5, \$10, or \$30.

What if your local government were considering methods to prevent companies like this from coming to your area? Would you be willing to vote for a program that would cost you t_s *dollars in one-time taxes to prevent biofuel plants from being built in your community?*

[2] Simulations by Alberini (1995) indicate that, for a 960 sample size survey using single bounded dichotomous choice question, 6 to 12 sub-groups/bid-values have better powers than other numbers of sub-groups.

5. Estimation

The conceptual model is similar to the conventional WTP estimation models except that the model is conditional on attitude toward the biorefinery:

$$Prob_s(Y = 1|Z, t_s) = 1 - G(\boldsymbol{Z\beta}, \theta t_{\boldsymbol{s}})$$

The variable Y is a dummy representing the WTP response and t_s is a bid value as defined above. We index support/opposition towards the biorefinery with *S*. The set of individual characteristics and socio-economic variables are represented with $\boldsymbol{Z}$. We include race, political ideology and their interaction term with gender because these factors are likely to influence the attitudes towards issues of climate change (McCright and Dunlap, 2011).

The county level variables include urbanization level as represented by USDA's 2013 Rural-Urban Continuum Codes; dummies for counties with more than $20M increase or decrease in oil and natural gas production in 2000 - 2011; poverty rate; unemployment rate; and a set of agricultural variables. Several variables characterized the nature of the county's agriculture: median farm size, as well as the value of corn, milk, nursery and vegetable sales. We include a temperature variable because Lee et al. (2014) found local acceptance can be influenced by temperature spikes and variations. The model also includes a dummy variable representing if the respondents have a computer at home (a proxy for access to information); and it is then employed as the exclusion restriction which ensures that the Heckman process is credible (Wooldridge, 2010).

Our estimation procedure assumes that the respondent follows a two-step decision process, i.e. in the first stage they decide on whether they would oppose or support the biorefinery, and in the next step they would decide whether they would be willing to pay the bid amount presented (in the questionnaire) in support of their selected position. Since the bid amount is conditional on their initial decision as to oppose or support of the biofuel facility, we use a Probit model[3] with sample selection (Wooldridge, 2010). We estimate the initial selection and the WTP estimation models together using a maximum likelihood procedure, which prevents the worse potential bias in a non-linear regression when the selection model were to be estimated separately (Freedman and Sekhon, 2010).

Since the WTPs condition on the attitudes toward the biorefinery, we carry out two separate set of estimations. The first set estimates the selection model where supporters are coded as 1 and the subsample of supporters is used in estimating the WTP equation. In the second set opponents are coded as 1 and the subsample of opponents is used in estimating the WTP equation.

6. Results

The first stage question, whether the respondents support or oppose the facility, can be analyzed as a simple poll. About two thirds of respondents (65%[4]) said they support the biorefinery while 27% of them were against it. The remainder, about 8%, chose “don’t know” or refused to answer the question. If we only take the respondents who revealed their attitudes into consideration, 70.4% support the project. The survey summary statistics are reported in Appendix Table A.1.

Table 1 reports the key advantages or drawbacks selected by respondents, in support of their position, from a list developed via an open-ended pretest question. While the supporters tended to select jobs benefits, opponents appear to focus on the possible negative “social” externalities

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[3] We employ the ‘heckprobit’ command in Stata 14.
[4] If not specified, the results reported are from weighted data.

such as environmental pollution, and economic infeasibility, and not so much on the personal negative impacts most typically associated with NIMBYism (e.g., smell/noise, congestion).

Table 2 shows the distribution of "yes" responses to the WTP question for supporters and opponents under various bid amounts for WTP in support of their position. One would expect as bid values increase, the percent of respondents willing to pay the bid value would decline. The distribution of supporters' "Yes" response to the presented WTP question in general[5] follows this non-increasing assumption while the opponents' "yes" distribution is ambivalent. However, it is not rare to have an empirical distribution somewhat violating the assumption in choice experiments.[6]

Table 1 Reasons for Supporting or Opposing the Biofuel production facility (% of respondents choosing)

Supporters (N=660)	Biggest Advantage	Smallest Advantage
Job Creation	45.2	7.58
Increased Sales for Area Farmers	11.1	15.8
Environmental Benefits	10.3	18.3
The Plant would Pay Local Taxes	8.6	20.5
Reducing Dependence on Foreign Oil	22.3	28.9
Opponents (N=353)	Biggest Drawback	Smallest Drawback
Daily Smells or Noises	7.4	15.0
Long-term Environmental Effects	26.4	6.2
More Trucks on the Road	5.1	28.9
Risk of Industrial Accidents	2.8	11.1
Biofuels Not Economically Viable	33.1	9.9
Biofuels Increase Food Prices	13.3	12.5

[5] Without imputation, the supporters' "yes" distribution is strictly non-increasing.
[6] For example Haab & McConnell (Haab and McConnell, 2002) document empirical studies violating the non-increasing assumption.

Table 2 Summary of WTP Responses

	Supporter				
Bid offer ($)	1	5	10	30	100
Yes Response (%)	83.7	91.4	79.7	68.7	62.2
N	13	29	96	325	197
	Opponent				
Bid offer ($)	1	3	5	10	30
Yes Response (%)	58.8	24.2	41.6	42.1	26.7
N	13	27	59	159	95

* The percentage and number of observation are not weighted.

The selection model regression results are shown in Table 3. The ρ statistics (*athrho*) reported in the last row support the maintained hypothesis of sample selection bias in conditional estimation of the WTPs and validate the use of the Heckman process. Overall, most respondent demographic variables are not significant except for race in the opponent selection model. The statistically significant coefficients on the county level variables suggest that the decision to support or oppose the biorefinery is more likely to be influenced by the community characteristics rather than individual heterogeneity.[7] For instance, the dummy variable which indicates if the county had a significant increase (at least 20 million) of oil and natural gas production in the first decade of 21st century, is significant at 5% level. The significant (at 5% level) negative coefficients on urbanization variables also imply that, less urbanized areas (relative to metropolitan area with >1 million population) are more likely to oppose the biorefinery. This result is somewhat different from Haddad et al. (2009)'s finding that, from the perspective of existence of bio-ethanol plants, a higher density of population has a negative

[7] Consistent with emerging literature we control for ambient temperature conditions the day of the survey. According to AIC, models with temperature deviation from average perform better than those using temperature per se. Both the *temperature* and *temperature deviation* are negative in supporters' WTP but not significant for opponents' WTP (Appendix Table A.2). We define the comfortable temperature zone as 60°F - 65°F and construct a dummy variable to index it. The *temperature* and *temperature deviation* are interacted with the dummy variable to identify the influence temperature within or outside the comfortable zone. The non-interaction terms are negative while the interaction terms are positive but insignificant (Appendix Table A.3).

association with the plants' location choice. However, our finding is consistent with Fortenbery et al.(2013). It is not surprising that, from local resident's view, a less urbanized community may be more concerned with higher levels of environmental amenities which could be endangered by a biorefinery.

The county poverty rate influences the attitudes toward the biorefinery with the expected signs (significant at the 5% level). Higher poverty rate results in higher probability to support and lower probability to oppose such a program. Median farm size as well as nursery sales[8] also have effects on the attitudes (significant at 10% and 5% level, respectively). The larger the median farm size in the respondent's county, the less likely the respondent would oppose the biorefinery. On the contrary, sales nursery has the negative effect on the support of the program.

Table 4 shows the estimation result of WTP conditional on the decision to oppose or support the biofuel facility. Similar to the selection model, individual characteristics are mostly not significant except for *conservative* in supporter's WTP and the interaction variable *Conservative *White*Male* in opponent's WTP. The significant county level variables in the WTP estimations are different from those in the selection model. For instance, the urbanization level is not significant in supporter's WTP. However in the case of opponents, coefficients of urbanization levels are negative and significant (at 5-10%) implying that the opponents from less urbanized counties are less willing to pay for preventing the biorefinery.

The coefficient of the dummy variable for the considerable increase of oil and natural gas production in the supporters' WTP is positive, which may seem counterintuitive because people may assume bio-energy production is a substitute for conventional energy. The possible alternative explanations are: (a) supporters from those counties are already familiar with

[8] We transform the sales variables except for corn sales through inverse hyperbolic sine function to reduce the multicollinearity among these variables.

externalities associated with energy production and hence more supportive of bioenergy, (b) they or their friends have skills sets that might be employed in such a facility, and/or (c) they think that bioenergy can reduce the adverse impacts of conventional energy sources. Both increase and decrease of oil and natural gas production have positive coefficients in the opponents' WTP.

Poverty rate is positive in both supporter and opponent WTP estimates. This result may appear contradictory. However, conditional on the attitudes, the supporters from poorer counties may believe the biorefinery will lead to the increase of their welfare due to jobs, while the opponents from poorer counties may believe the plant would bring negative impact to their welfare due to pollution and sites closer to poor neighborhoods.

The coefficients of agriculture variables imply that the strength of local acceptance might depend on agriculture commodities. While we cannot reject the hypothesis that *corn sales* has no influence on supporters' WTP, its positive coefficient on opponents' WTP, significant at 5% level, indicates that residents, conditional on the attitude, from counties with more sales of corn are more likely to perceive welfare loss from the biorefinery.

The supporter's average WTP is \$59.2 and the opponent's average WTP is \$95.7 per person. This confirms our suspicion that even though there are more residents who support the biorefinery, a simple poll may not properly reveal the strength of local acceptance/opposition. We can calculate the weighted proportion of supporters and opponents through the raw survey data. Taking the proportion mentioned at the beginning of this section (70.4% for supporter and 29.6% for opponent), we further weight the WTPs to calculate the total residents' WTPs in Michigan. The total supporters' WTP versus the total opponents' WTP at Michigan is 1.47:1. Although the net support for the biorefinery is still positive, the results suggest that opposition may be much stronger and financially better supported than what a simple poll might suggest.

Table 3 Regression Results: Selection Model

	Supporter		Opponent	
Temperature Deviation (Daily Max)	-0.000	(0.004)	0.000	(0.004)
Age	-0.004	(0.019)	0.010	(0.018)
AgeSQ	-0.000	(0.000)	0.000	(0.000)
Income > 50 K	-0.041	(0.114)	-0.037	(0.112)
Less than H.S.	0.200	(0.331)	-0.310	(0.348)
Some College	-0.063	(0.178)	0.017	(0.180)
More than College	0.077	(0.112)	-0.143	(0.116)
Male	0.215	(0.164)	-0.195	(0.160)
White	0.127	(0.117)	-0.203*	(0.119)
Conservative	-0.124	(0.193)	0.179	(0.187)
Conservative White Male	-0.138	(0.190)	0.133	(0.175)
Oil & Natural Gas Production Decrease	0.393	(0.334)	-0.291	(0.321)
Oil & Natural Gas Production Increase	0.745**	(0.318)	-0.685**	(0.338)
Urbanization Level				
2 (250K ⩽ Metro < 1M)	0.121	(0.208)	-0.085	(0.170)
3 (Metro < 250K)	-0.506**	(0.200)	0.557**	(0.196)
4 (Urban ⩾ 20K, adj to Metro)	-0.487	(0.343)	0.437	(0.273)
5 (Urban ⩾20K, not adj to Metro)	-0.860**	(0.356)	0.993**	(0.361)
6 (Urban < 20K, adj to Metro)	-0.761**	(0.365)	0.814**	(0.305)
7 (Urban < 20K, not adj Metro)	-0.429	(0.348)	0.610*	(0.321)
Poverty Rate	0.024**	(0.009)	-0.023**	(0.009)
Unemployment Rate	-0.065	(0.086)	0.095	(0.079)
Home Computer	0.110	(0.152)	0.172*	(0.104)
Median Size of Farm Land (acres)	0.007	(0.004)	-0.008*	(0.004)
Milk Sale IHT	0.027	(0.053)	-0.025	(0.052)
Nursery Sale IHT	-0.151**	(0.047)	0.156**	(0.056)
Vegetable Sale IHT	0.048	(0.060)	-0.069	(0.055)
Corn Sale ($1M)	-0.000	(0.003)	0.002	(0.003)
Constant	0.384	(0.640)	-0.651	(0.572)
athrho	2.340***	(0.461)	-12.428***	(0.219)
N	907		907	

Standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.001

Table 4 Regression Results: WTP Estimation

	Supporter		Opponent	
WTP Bids	-0.004***	(0.001)		
WTP Bids			-0.010**	(0.004)
Temperature Deviation (Daily Max)	-0.011**	(0.005)	-0.000	(0.006)
Age	-0.000	(0.019)	-0.012	(0.019)
AgeSQ	-0.000	(0.000)	0.000	(0.000)
Income > 50 K	0.098	(0.141)	0.072	(0.160)
Less than H.S.	0.200	(0.355)	-0.072	(0.390)
Some College	0.018	(0.191)	-0.207	(0.169)
More than College	0.101	(0.118)	-0.165	(0.184)
Male	0.099	(0.143)	0.309	(0.202)
White	0.190	(0.173)	0.153	(0.181)
Conservative	-0.364**	(0.160)	0.153	(0.239)
Conservative White Male	0.136	(0.205)	-0.429**	(0.203)
Oil & Natural Gas Production Decrease	-0.269	(0.319)	0.652*	(0.371)
Oil & Natural Gas Production Increase	0.672***	(0.150)	0.603*	(0.334)
Urbanization Level				
2 (250K ⩽ Metro < 1M)	0.258	(0.220)	-0.095	(0.230)
3 (Metro < 250K)	-0.362	(0.282)	-0.653**	(0.287)
4 (Urban ⩾ 20K, adj to Metro)	-0.058	(0.377)	-1.058**	(0.431)
5 (Urban ⩾20K, not adj to Metro)	-0.136	(0.395)	-0.758*	(0.431)
6 (Urban < 20K, adj to Metro)	-0.067	(0.450)	-0.997**	(0.367)
7 (Urban < 20K, not adj Metro)	-0.178	(0.414)	-0.347	(0.431)
Poverty Rate	0.019**	(0.009)	0.030**	(0.012)
Unemployment Rate	-0.111	(0.092)	-0.130	(0.108)
Median Size of Farm Land (acres)	0.002	(0.004)	0.006	(0.007)
Milk Sale IHT	-0.051	(0.052)	0.047	(0.074)
Nursery Sale IHT	-0.133**	(0.044)	-0.147*	(0.083)
Vegetable Sale IHT	-0.020	(0.052)	-0.030	(0.072)
Corn Sale ($1M)	0.004	(0.003)	0.007**	(0.003)
Constant	0.167	(0.551)	0.901	(0.549)
N	601		306	

Standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.001$

7. **Spatial Analysis**

Since attitudes and the valuations of the biorefinery appear to be strongly determined by several county level variables, we offer a spatial analysis using county level averages. Figure 1 shows the proportion of the respondents who support the biofuel facility in each county calculated from the result of first stage question.[9] For the whole State of Michigan, as we reported in section 6, the total supporters' proportion is about 70%. For some counties, however, their supporters' proportions are much lower than 50%. We can also find extremely high or low proportions in Figure 1. The supporters' proportions at county level are somewhat misleading because of the small sub-sample sizes. Although the survey has about 1,000 observations and weights the data to represent the actual population distribution across Michigan, some counties have few observations[10] and hence the attitudes towards the biorefinery might be mis-estimated at the county level. Due to this limitation, a survey designed at the scope of a State can hardly be used to explore local acceptance at county level without such concern of bias. At the early stage of searching a location for biorefinery investment from counties statewide, if the decision maker uses a statewide poll to explore the local acceptance, to prevent the possible bias at small scope, the poll would need more than 1,000 observations, which would result in high cost.

Figure 2 shows the ratio of supporters' WTP over total WTP, which is the summation of supporters' and opponents' WTP.[11] We find that, when the welfare change is taken into consideration, some counties have stronger tendency to support a biorefinery. Meanwhile, the

[9] We test the spatial correlations of the attitudes and WTP responses using Moran's I and Geary's C. The results suggest that there is no global spatial correlation.
[10] One county has no observation, 10 counties have 1 observation, 58 counties have less than 10 observations.
[11] Both the supporters' and opponents' WTP are weighted by the corresponding proportions. The supporters' proportion is predicted from the results of Table 3. We use Romney's 2012 U.S. presidential election result in each county in Michigan to approximate the mean value of conservative political ideology.

ratios in Figure 2 are not as extreme as the proportions in Figure 1, which implies the WTP ratio may be a better index of local acceptance.

We further compare the supporters' proportion[12] to the supporters' WTP ratio, and find that, in some counties, the proportion is larger than 50% while the ratio is less than 50% (Figure 3). This implies that, although the majority supports the biorefinery, total welfare gain is less than the total welfare loss. In these counties, while a poll could show that opponents are a minority, the opposing actions might be more severe than expected. This result validates our concern about the use of polls to measure local acceptance. The investment of a biorefinery may face higher risk due to local opposition.

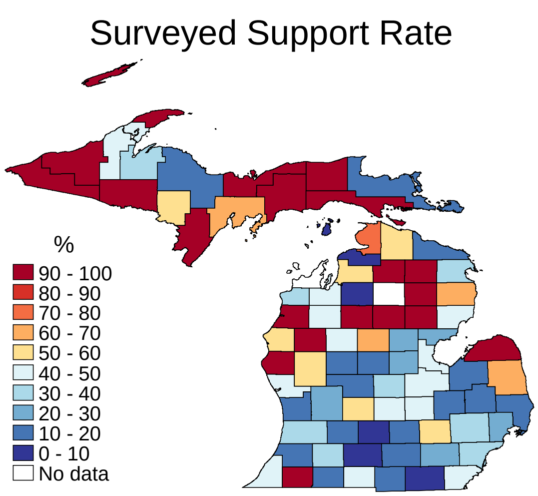

Figure 1 Proportion of Supporters from Weighted Survey Data

[12] The supporters' proportion is predicted by the results of Table 3 since, as Figure 1 shows, the proportions calculated directly from survey data can be misleading. Even if we use the surveyed proportions instead of the predicted proportions, we can still find counties with a majority of supporters and negative welfare change (Appendix Figure A.1).

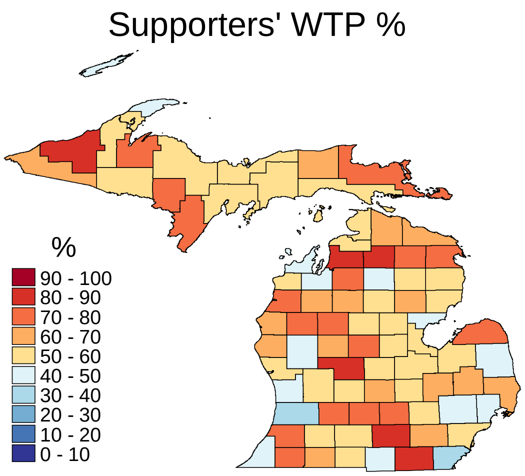

Figure 2 Supporters' WTP among Total WTP

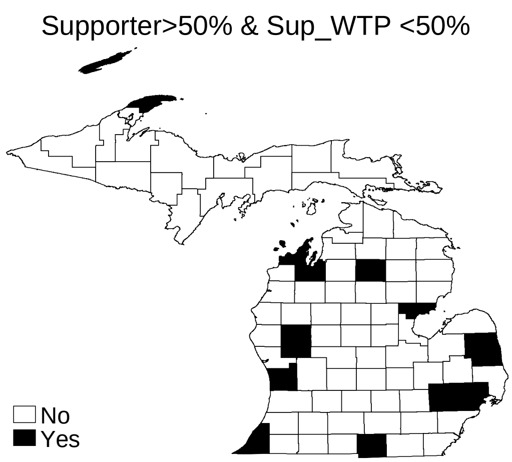

Figure 3 Counties where a Majority Supports the Biorefinery, but the Opponents' WTP Outweighs Supporters' WTP

8. Discussion and Conclusion

While a biofuel facility would have various kinds of positive and negative impacts on the community where it is located, local acceptance is more complex than a yes/no question about the facility. Our study proposed a WTP protocol to access not only the attitudes but also the strength of local acceptance through the welfare change of local residents. We used a two stage method to estimate the WTPs conditional on the residents' attitudes toward a proposed biorefinery since such a facility can have both positive and negative externalities, which renders the conventional non-negative assumption for WTP estimation invalid.

Our first stage question was a poll of attitudes regarding a proposed biorefinery located in the respondent's community. More than two thirds of Michigan respondents were in favor of such a project going to their community and the key reasons were the potential economic benefits that the project may bring to the local community. The opponents were concerned about the environmental effects, but not so much the highly localized issues typically associated with NIMBYism.

The estimates of mean WTPs further show the strength of the supporters' and opponents' welfare changes due to the biorefinery, which provides an approximation of local acceptance. The supporter's personal mean WTP is around $36 less than the opponent's WTP, confirming our suggestion that yes/no polls cannot reveal the welfare, thereby misjudging the level of local support/opposition. The relative strength of supporters and opponents of the biorefinery is estimated at 1.47:1 for the whole State of Michigan, which indicates the overall support, after taking the welfare gain and loss into consideration, is positive but weaker than what a simple poll might indicate. Our analysis also shows that, at county level, this problem can be worse and some counties may suffer net welfare loss while a poll may find they have a majority of support.

The techniques employed in our analysis can help investors and policy makers choose the location for a biorefinery or other energy facility. Because most significant variables are county level variables, investors or decision makers could potentially adopt the calibrated model instead of conducting a survey with larger sample size for their search of sites at the early stage in which they are choosing candidate sites. Potential sites can be signaled by the WTP ratio while investors might want to be more cautious in counties or places where the ratio is smaller than 1.

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Appendix A

Table A.1 Variable Description

Variable	Mean	Standard Errors
Daily Max Temperature Deviates from 30 Year Normal (^{o} F)	1.0	(0.633)
Age	46.2	(0.777)
Income > 50 K (%)	55.4	(0.023)
Education Level Less than H.S. (%)	3.3	(0.007)
Education Level With Some College (%)	33.7	(0.022)
Education Level More than College (%)	41.9	(0.022)
Gender (Male=1) (%)	49.2	(0.023)
Race (White=1) (%)	78.3	(0.020)
Political Ideology is Conservative (%)	36.1	(0.021)
Conservative White Male (%)	16.5	(0.015)
Oil & Natural Gas Production Decrease (>$20 M in 2000 ~ 2011 = 1) (%)	3.1	(0.007)
Oil & Natural Gas Production Increase (>$20 M in 2000 ~ 2011 =1) (%)	2.9	(0.009)
Urbanization Level (%)		
2 (250K ≤Metropolis Population < 1M)	28.6	(0.020)
3 (Metropolis Population < 250K)	13.4	(0.015)
4 (Urban Population≥ 20K, adjacent to Metropolis)	4	(0.009)
5 (Urban Population≥20K, not adjacent to Metropolis)	3.5	(0.007)
6 (Urban Population < 20K, adjacent to Metropolis)	4.1	(0.008)
7 (Urban Population< 20K, not adjacent Metropolis)	6.2	(0.008)
Poverty Rate (%)	17.1	(0.257)
Monthly Unemployment Rate Deviated from 5 Year Average (%)	-1.7	(0.029)
Home Computer (%)	87.8	(0.014)
Median Size of Farm Land (acres)	43.2	(0.916)
Milk Sales ($1M)	14.9	(0.874)
Nursery Sales ($1M)	22.8	(1.292)
Vegetable Sales ($1M)	5.6	(0.384)
Corn Sales ($1M)	25.5	(1.058)
Observations	907	

+ Mean of county level variable is sample average

Table A.2 Test of Non-linearity of Temperature on Supporters' WTP

Model	S1	S2
Temperature	-0.011**	-0.052
	(0.005)	(0.046)
Temperature SQ		0.001
		(0.001)
Model	S3	S4
Temperature Deviation	-0.011**	-0.022**
	(0.005)	(0.010)
Temperature Deviation SQ		0.001
		(0.001)

+ Temperature or temperature deviation and their square terms (in model O1 ~ O4) are in general not significant for opponents' WTP.
++ The control variables are all the same as the regressions in the main text except for the vegetable sales is not transformed due to non-convergence caused by the transformed variable in one opponent's regression.
+++ Standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.001

Table A.3 Temperature Interaction with Comfortable Zone Dummy

	Supporter WTP	Opponent WTP
Model	S5	O5
Temperature	-0.014**	-0.007
	(0.004)	(0.008)
Temp.* Comfortable Zone	0.007	0.033**
	(0.010)	(0.010)
Model	S6	O6
Temperature Deviation	-0.014***	-0.007
	(0.004)	(0.007)
Temperature Deviation * Comfortable Zone	0.014	0.068**
	(0.021)	(0.021)

+ The control variables are all the same as the regressions in the main text except for the vegetable sales is not transformed due to non-convergence caused by the transformed variable in one opponent's regression.
++ Standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.001

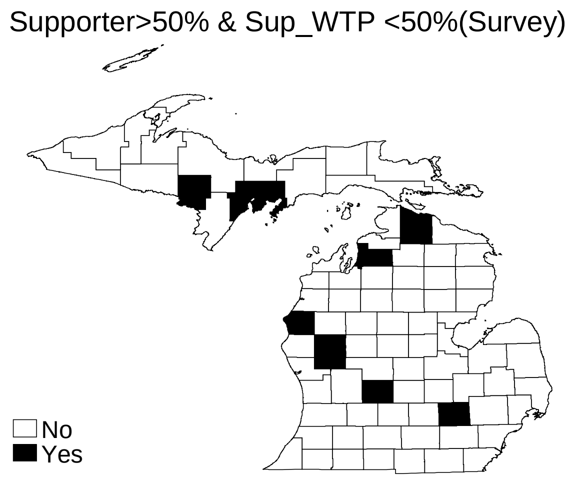

Figure A.1 Counties where a Majority Supports the Biorefinery, but the Opponents' WTP Outweighs Supporters' WTP: Supporters' Proportion Calculated Directly from First Stage Question (Poll)