

Preliminary Market Analysis for a New Hybrid Electric Farm Tractor

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Abstract—A survey was administered with 101 participants from the agriculture communities in California and Texas to analyze potential market acceptance for a hybrid electric farm tractor (HET) and to identify factors influencing purchase decisions. The preliminary results suggest that reliability is a deterministic factor and farmers are willing to pay more for a reliable unit. The primary benefits of hybrid technology, namely fuel efficiency and reduced air pollution, are not major factors affected purchase decisions. Probit analysis results show that a farmer with more than 50 years work experience is less willing to purchase an HET. Those who are willing to pay a high maintenance cost are more likely to purchase an HET. However, farmers' age has a stronger impact such that even an older farmer may budget a relatively high maintenance cost, he is less likely to purchase the HET. Successful marketing strategies of an HET rely on customer education help them understand the farm-level benefits of using hybrid electric technology.

Keywords- farm adoption; diffusion of tractor; hybrid; alternate fuels; hybrid electric tractor

I. INTRODUCTION

A. Statement of the Problem

In the automotive industry, with the rising cost of fuel, the demand for hybrid electric vehicles has been rapidly growing, generating lucrative profits for manufacturers. As a result, the automotive industry has created a separate account known as hybrid electric vehicle sales. The utilization of hybrid electric vehicles in the agricultural industry has not been fully explored. Currently there are no hybrid electric farm tractors being produced or sold in the United States and yet the United States is home to some of the largest agricultural producers in the world. If a hybrid electric farm tractor were to be introduced into this untapped agricultural farm tractor market, would farmers accept the technology and be willing to purchase a tractor of this kind? The primary purpose of this study is to determine the agricultural communities' willingness to pay for the benefits of a hybrid electric farm tractor. Even though the marketing of automotive hybrid electric vehicles has been a relative success, it does not mean that a hybrid electric farm tractor will be accepted. A secondary purpose of the study is to determine what primary factors would most influence the acceptance of a hybrid electric farm tractor.

B. Significance of the Problem:

Hybrid electric technology has been proven to be a successful technology. But there are currently no farm tractors of this nature known to be in production for use in agriculture at this time. With the push for alternative fueled technology and environmentally friendly technology, hybrid technology has been seen by many researchers, including myself, as the most promising technology for the near future. Hybrid technology does not necessarily offer a solution to petroleum dependence; however, it does offer superior fuel efficiency and lower emissions than traditional internal combustion engine equipment. All three major alternative fuel technologies offer fuel cost savings, however, electric vehicle technology has a limited operating range which makes it less desirable, and fuel cell technology is very expensive. Therefore, it is the view of many researchers, including myself, that hybrid electric technology is the most likely alternative fuel technology to be able to offer desirable operating range, superior fuel efficiency, and lower emissions at a manageable market price for consumers. In general, hybrid electric technology tends to be more expensive than traditional internal combustion engine technology but it is still capable of keeping price competitive primarily due to the benefit of fuel cost savings. In addition, some manufacturers claim that their hybrid products have lower operating costs, less maintenance cost, and improved reliability. There are also some consumers, especially in the passenger vehicle market, that prefer the technology due to the fact that it offers lower emissions and reduced air pollution in comparison to other technologies. A market analysis with the intent of evaluating the acceptance of hybrid electric technology for farm tractors has not been performed. This preliminary research will serve as an indicator of the likelihood of the success of a hybrid electric farm tractor if one were to be produced.

C. Limitations

The research was conducted as a qualitative study with a convenience sample. This research was limited to the agricultural communities of the Central Valley in California and the surrounding area of Abilene, Texas. Survey respondents represent a wide range of members from the agriculture community including: large scale farms, medium sized farms, small family farms, agricultural crop advisors, farm mechanics, field managers, tractor and equipment dealers, ranchers, dairymen, agriculture salesmen, and others.

D. Summarization of Related Research

Initial research showed that limited work has been performed on the development and viability of a hybrid electric farm tractor. As a result of the lack of information from prior published work, in this field, the researcher felt that the relationship between internal combustion engine passenger vehicles and hybrid electric passenger vehicles could be compared, in principle, as representative of the relationship between traditional internal combustion engine tractors and the proposed hybrid electric farm tractor. There are varying degrees of hybridization from full hybrid, to light hybrid, and the integrated starter generator. It would appear that the agriculture community and specifically equipment manufacturers are interested in exploring the possibility of producing a hybrid electric farm tractor. Caterpillar has proven the capability of the technology and has exposed many of the other benefits that could be realized by a hybrid electric farm tractor (“D7E Track-Type Tractor” 2012).

If the sales and market share of hybrid passenger vehicles are presumed to be representative of the market sales that could be expected for hybrid farm tractors, then one may expect the market share to be near 2.4% of all tractors sold within 12 years of launching the product. However, there are other factors that may differ from the passenger vehicle market to the agricultural farm tractor market (“Hybrid electric vehicles in the United States”, 2012).

II. METHODOLOGY

Members of the agriculture community of the Central Valley in California as well as Abilene, Texas were targeted to participate in the survey. The opinions of farmers from both of these areas are likely to provide a good representation of the potential desirability of a hybrid electric farm tractor. The pattern for evaluating the market and formulating questions was derived from a previous work by Dr. Xu et al. (2012). The survey was developed with the intent of analyzing tractor purchase decisions based on five factors, namely purchase price, air pollution, fuel efficiency, reliability, and the aspect of new technology in terms of maintenance and repair. The survey consists of 22 questions total. Of those questions, numbers 1-8 are demographic questions and questions 9-22 relate to the specifically identified purchase decision factors for farm tractors and the proposed Hybrid Electric Tractor. Two hundred fifty surveys were distributed by mail or by hand. Two hundred twenty were distributed in California and 30 were distributed in Texas. One hundred ten completed surveys were returned, nine of which could not be used.

General tendencies of respondents about the frequency, percentage, cumulative percentage, standard deviation, and statistical mean of respondents’ answers were generated from the data analysis. Further information was derived from performing a linear regression and a probit regression analysis. Results from such an analysis simply indicate whether or not a correlation exists between the independent variables and the dependent variable. The dependent variable for the regression is the willingness to buy a hybrid tractor when one becomes available. There were eight selected independent variables that were used to perform the regression. The independent variables included: age, experience, acreage, number of employees,

maintenance cost, farm land location, hybrid knowledge, and the importance of tractor purchase price.

III. RESULTS

A. General Tendencies Purchase Decision Ranking

The respondents were asked to rank the five purchase decision factors from five to one. The ranking scale described five being the most important and one being the least important. This question was used to evaluate the relative importance of each purchase decision factor in comparison to each of the other factors. Figure 1 below clearly depicts that the majority of respondents agree that when purchasing a farm tractor, reliability is the most important factor and pollution of the equipment is the least important factor. The other factors such as purchase price, fuel efficiency, and self repair were fairly close to each other in their distribution in the graph. Technically the data tabulation indicates that the majority of respondents ranked the five factors, from most important to least, as reliability, purchase price, fuel efficiency, self repair, and pollution.

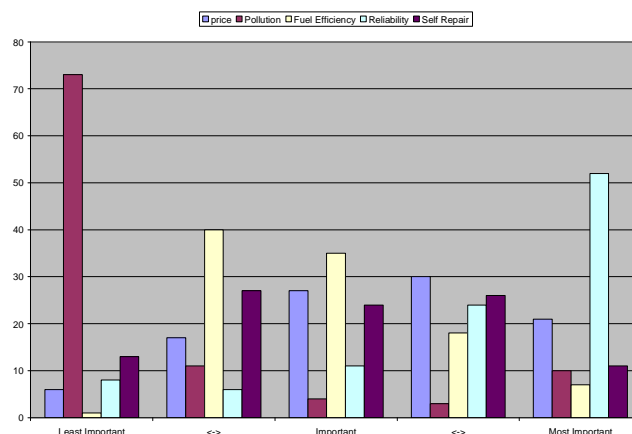


FIGURE 1. PURCHASE DECISION IMPORTANCE FACTOR RANKING

It is interesting to note that the price of the equipment is not necessarily the most important factor when making a purchase decision. The ranking of the factors reveals that reliability is seen by many of the respondents as a more significant factor than the other four factors. It is likely due to the nature of farming because tractor work often must be done at precise times. If equipment breaks down there is the potential that the cost of the delay may far exceed the difference in purchase price between one tractor or another. This would imply that farmers may be willing to pay more for a tractor that is deemed to be more reliable.

B. Linear and Probit Regression

The data tabulations were performed to represent a 90% confidence level based on the fact that the code was written to reflect that confidence level. A correlation was considered to be statistically significant at the 0.1 level which indicates that we are 90% sure the results are valid. The primary dependent variable for this model is willingness to buy a hybrid tractor when one becomes available. The independent variables were age, experience, acreage, number of employees, maintenance

cost, farm land location, hybrid knowledge, and the importance of tractor purchase price. Table 1 gives the code and explanation for the independent variables.

TABLE 1. VARIABLE CODES AND MEANINGS (2013 DATA)

<i>Variable Code</i>	<i>Variable Code Meaning</i>
age1	Age
years1	Years farming or working in agriculture
acres1	Amount of acreage
hire1	Number of employees
maintc1	Annual maintenance cost
county2	Farm land location
hybridk1	Level of knowledge about hybrid technology
price1	The importance of tractor purchase price

The results of the regression show significant correlation between the independent variables and the dependent variables in some cases but not in others. In the case of the government subsidization of the purchase price of an HET, Table 2 indicates that a relationship exists between annual tractor maintenance cost and the government subsidizing the price difference of the HET. The data suggests a correlation between maintenance cost over \$10,000 and government subsidization of an HET as they relate to the willingness to buy a hybrid tractor when one becomes available. The significant data in the table is highlighted in red.

TABLE 2. PROBIT ANALYSIS: GOVERNMENT SUBSIDIZED PRICE (2013 DATA)

<i>sub2</i>	<i>Coef.</i>	<i>Std. Err.</i>	<i>z</i>	<i>P> z </i>	<i>[95% Coef. Interval]</i>
age1	0.0558031	0.4160058	0.13	0.893	-0.7595534, 0.8711595
years1	-0.5718077	0.4817966	-1.19	0.235	-1.516112, 0.3724963
acres1	-0.1747318	0.3444267	-0.51	0.612	-0.8497957, 0.5003321
hire1	0.1579973	0.3412668	0.46	0.643	-0.5108733, 0.8268679
maintc1	0.6067856	0.3472196	1.75	0.081	-0.0737523, 1.287323
county2	-0.0900211	0.3808047	-0.24	0.813	-0.8363845, 0.6563424
hybridk1	0.2919438	0.3056335	0.96	0.339	-0.3070869, 0.8909745
price1	-0.1917141	0.3561073	-0.54	0.59	-0.8896715, 0.5062434

Table 3 provides the results from the multivariate probit regression model analysis for a “likely HET purchase.” The results indicated a correlation of two variables including years1 and maintenance, with the dependent variable of willingness to buy a hybrid tractor when one becomes available. The independent variables years1 and maintenance were identified as significant because their test data was below the .1 value. In the case of the variable maintc the coefficient is positive which indicates a correlation for the HET purchase decision when maintenance costs are greater than \$10,000. In the case of year1 the coefficient is negative with a correlation for over 50

years experience having a negative effect on the HET purchase decision.

TABLE 3. REGRESSION ANALYSIS: LIKELY HET PURCHASE (2013 DATA)

<i>avail</i>	<i>Coef.</i>	<i>Std. Err.</i>	<i>t</i>	<i>P> t </i>	<i>[95% Coef. Interval]</i>
age1	0.1689592	0.1360915	1.24	0.218	-0.1014103, 0.4393287
years1	-0.3807917	0.1733872	-2.2	0.031	-0.7252557, -0.0363277
acres1	-0.0411765	0.1123798	-0.37	0.715	-0.2644385, 0.1820855
hire1	0.1151169	0.1095418	1.05	0.296	-0.102507, 0.3327408
maintc1	0.1927602	0.109072	1.77	0.081	-0.0239303, 0.4094507
county2	0.058318	0.1280433	0.46	0.65	-0.1960624, 0.3126984
hybridk1	0.144066	0.1001227	1.44	0.154	-0.0548452, 0.3429771
price1	-0.1620164	0.1141566	-1.42	0.159	-0.3888083, 0.0647755

Three findings came as a result of the linear regression and the probit regression analysis. It can be concluded that the willingness to buy a hybrid tractor when hybrid tractors become available is increased by 0.1928 for farmers who spend more than \$10,000 in tractor maintenance annually relative to those who spend less than \$10,000 annually with a 90% level of confidence. The willingness to buy a hybrid tractor when hybrid tractors become available is decreased by 0.3808 for farmers who have spent more than 50 years farming or working in the agricultural industry relative to those with less than 50 years with a 90% level of confidence. It can also be concluded from the data that farmers having more than 50 years experience has a greater effect on their willingness to buy a hybrid tractor compared to whether they spent more than \$10,000 annually on tractor repairs.

The regression for “Government Subsidized Price” and “Likely HET Purchase” both show a correlation between maintenance cost and willingness to purchase an HET when one becomes available. The following is a generalized summary of the findings from the regressions. A farmer having more than 50 years work experience correlated to a negative effect on the willingness to purchase an HET. Higher maintenance cost, over \$10,000, correlated to increased willingness to purchase an HET. The results suggest that having over 50 years work experience in agriculture tends to have a stronger effect on the purchase decision of an HET than high maintenance cost over \$10,000.

IV. SUMMARY AND CONCLUSIONS

In more recent years there has been a push for alternative fuels and alternative fuel technology. Hybrid electric technology is being used in a wide spectrum of applications including: locomotives, heavy earth movers, passenger vehicles, and heavy equipment. There are benefits to the use of hybrid electric technology over traditional technology in all of those applications. The noted primary benefits of hybrid technology include increased fuel efficiency and reduced air pollution but other benefits would also include: lower operating cost, less maintenance cost, and excellent reliability and functional performance. The farm tractor market was identified as an

untapped potential market for hybrid electric technology. It was unknown whether or not the agricultural community would be likely to pay for the benefits of a hybrid electric farm tractor. It was also undetermined if the benefits of hybrid electric technology would be seen to add value to a farm tractor.

Preliminary market research was performed to determine the potential desirability of a hybrid electric farm tractor and to evaluate the factors that would significantly influence a purchase decision for an HET. The majority of the respondents worked or had farm land in the Fresno and/or Tulare counties which are two of the most productive agricultural counties in California. This fact would suggest that the information gathered from respondents is a significant representation of mainstream agriculture producers and members of the agricultural community. The sample of 101 respondents is considered likely to provide a good representation of the acceptance of a hybrid electric farm tractor.

Five factors including: purchase price, air pollution, fuel efficiency, reliability, and self repair were evaluated for their individual importance and relative importance when purchasing a farm tractor. The study suggests that the primary benefits of hybrid technology namely, fuel efficiency and reduced air pollution are not major purchase decision factors for farm tractors. The majority of respondents agreed that reliability (84%) and purchase price (59%) are extremely important factors when purchasing a farm tractor. Close to 50% of respondents indicated fuel efficiency and being able to repair the equipment themselves to be extremely important. The majority of respondents agree that reliability and not price is the most important factor when purchasing a farm tractor. This may imply that farmers may be willing to pay more for a farm tractor that is deemed to be more reliable. The survey also suggests that the majority of respondents view air pollution emitted by a tractor as a factor that is important; however, responses suggested that it is not something that is seen to add value to their purchase decision.

A combined 75% of respondents indicated that they were performing some higher level of technical repairs on their equipment. The perception of the hybrid electric technology from the majority of respondents is that the technology would be more expensive to maintain. However, the use of hybrid drive train technology actually results in the elimination of many conventional drive train components; therefore the potential for lower maintenance costs than traditional equipment is actually increased. Reliability is also increased for the same reason because there are fewer components to break down. The survey revealed that 91% of respondents felt that they were either uninformed or had only some knowledge of hybrid electric technology. This information would suggest that the before mentioned errant perception may be having a negative affect on the overall perception of the proposed hybrid electric farm tractor. Additionally, the survey suggests that the majority of respondents view self repair to be important to extremely important and are also actually performing their own repairs on tractors but they errantly perceive the HET as likely to cost them more to maintain. This information would suggest that the potential success of an HET would likely be linked to customer education regarding the benefits of hybrid electric technology over traditional technology.

The results of the regression show significant correlation between the independent variables and the dependent variables in some cases but not in others. We can conclude the following:

1) The willingness to buy an HET when HETs become available is increased by 0.1928 for farmers who spend more than \$10,000 in tractor maintenance annually relative to those who spend less than \$10,000 annually, with a 90% level of confidence.

2) The willingness to buy an HET when HETs become available is decreased by 0.3808 for farmers who have spent more than 50 years farming or working in the agricultural industry relative to those with less than 50 years farming, with a 90% level of confidence.

3) Whether farmers have more than 50 years experience has a greater effect on their willingness to buy an HET compared to whether they spent more than \$10,000 annually on tractor repairs.

The findings from this study show correlation but they are not conclusive enough to show that if a HET were to be produced that farmers would buy it. However the study has contributed to a better understanding of the factors that would influence the success of a hybrid electric farm tractor if one were to be produced. In addition to that the study has identified some of the key purchase decision factors for a hybrid electric farm tractor.

B. Recommendation for Future Research

If another study of this nature is performed it would be wise to assemble a research team comprised of industry professionals and experts as well as business marketing professionals and experts. These two groups will need to collaborate in order to successfully complete a study of this kind. The industry professionals are necessary to deal with the technical side of the study and the business marketing professionals are necessary to make sense of the market analysis side of the study. Both groups' contributions and expertise relative to their specific disciplines are necessary in order for a study like this one to be successful. By doing this the analysis should be more relevant and accurate.

That being said, there were questions other than "HET 25% more work," "Government Subsidized Price," and "Likely HET Purchase" that could have been chosen for further analysis that were not selected. Further research could be performed to analyze the other questions of the survey for correlations between the independent variables and the dependent variable. In addition to that, other independent variables could also be selected and used to further analyze the data. This may reveal more results and other implications for purchase decisions for an HET. In addition to that the conditions selected for analyzing the data with STATA could also be changed to reveal other possibly more meaningful results. For example, it is likely that a person with 50 years experience in the agriculture industry is at least 60-70 years old. Instead of categorizing the level of experience as more or less than 50 years, it may have been more meaningful to select 30 years experience instead. Improving the way that the data is displayed and represented would also improve the results and findings of this work or future work. It would be beneficial to

process the coefficient with the log function so that the results could be interpreted as a percentage and not the raw data number, which actually does not equate to a percentage. The research that was begun by this study has revealed findings that have contributed to a better understanding of the purchase decisions for a hybrid electric tractor but more work could still be done. Future research could also include a larger, more diverse distribution of the population. A larger sample size could include participants from many other states that farm in other parts of United States and provide a broader indication of the willingness to buy an HET when HETs become available.

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