

Article

Understanding Chinese Farmers' Behavioral Intentions to Use Alternative Fuel Machinery: Insights from the Technology Acceptance Model and Theory of Planned Behavior

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Abstract: Mitigating greenhouse gas emissions and reducing fossil fuel dependence have heightened interest in alternative fuels, particularly in agriculture, a key energy-intensive sector. This study investigates the use of the Technology Acceptance Model and the Theory of Planned Behavior to analyze Chinese farmers' behavioral intentions to adopt alternative fuel machinery. In 2023, a total of 281 full-time farmers were sampled from Jiangsu, Sichuan, and Hebei provinces, followed by path analysis conducted using PLS-SEM. The results underline that perceived usefulness $\beta = 0.369$, $p < 0.001$, and social norms $\beta = 0.185$, $p < 0.001$ are strong drivers for the adoption of alternative fuel machinery, while perceived barriers to operate and infrastructure gaps act as inhibitors. Also, perceived benefits $\beta = 0.235$, $p = 0.002$, and perceived behavior control $\beta = 0.157$, $p = 0.027$ positively predict behavior intentions. This thus suggests that improvement in the technological infrastructure and increasing farmers' awareness of the practical and economic benefits of alternative fuel machinery could result in a serious increase in adoption rates. This study does have weaknesses, as its focus on 50 mid-sized farms in the Midwest and utilization of self-reported data may limit the generalizability of its findings. This study, however, has major implications for policy and manufacturers to underscore the fact that targeted interventions through subsidies, training programs, and infrastructural development would be necessary to permit a transition toward sustainable energy in agriculture.

Keywords: clean energy; farmers' adoption; agriculture; Chinese farmers



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1. Introduction

Climate change is driven by anthropogenic emissions of carbon dioxide (CO₂) into the atmosphere, which has serious impacts on the global environment, such as global warming, intensified heavy rainfall, floods, permafrost thawing, and the decline in glaciers and snowpacks [1]. Globally, China is one of the largest CO₂ emitters [2]. Globally, China is one of the largest CO₂ emitters [3,4]. However, greenhouse gas emissions in carbon dioxide equivalents were reduced by nearly 9.9 billion tons in China between 1981 and 2020 [5]. In total, 13–21% of greenhouse gas emissions were accounted for by the agricultural sector, with emissions decreasing by approximately 13–21% from 1990 to 2020 [6]. Among the primary energy sources consumed in China, oil accounts for 30.60 oxyjoules, whereas natural gas accounts for 13.63 oxyjoules [7]. Thus, reliance on oil for power transportation and various industries constitutes a primary source of greenhouse gas emissions [8,9].

Accordingly, China aims to reduce its dependence on fossil fuels by accelerating the rollout of renewable energy sources [10]. Diesel is the primary fuel used in tractors and agricultural machinery [11]. Although substantial reductions in diesel fuel usage in agriculture are necessary [12], novel eco-friendly technologies must be developed and widely adopted, including alternative fuels for agricultural machinery [13–15].

While alternative fuels are produced by different technologies and feedstocks, they originally come from renewable energy sources; therefore, they do not have the problems concerning the scarcity of fossil fuels as well [16]. In this context, farmers play a double role in the alternative fuels market: they are both consumers and suppliers. As consumers, farmers use alternative fuels in farming processes, such as for machinery and irrigation purposes. Simultaneously, they are also producers through the production of bio-based feedstock, such as bioethanol and biodiesel, which is essential in the value chains for these fuels. This means that the farmer can switch back and forth between using and producing alternative fuels with great ease, making their income streams more resilient and their farming more compatible with the conservation of nature. On the one hand, they require substantial quantities of fuel for agricultural production, making them potential consumers [17]. Furthermore, according to [18], farmers can also serve as suppliers by cultivating raw materials, which are important alternative fuels. A farmer's perspective holds significant influence in implementing alternative fuel ideas in agriculture, particularly regarding economic considerations, environmental impacts, and practical applications [19]. Economically, farmers evaluate the cost-effectiveness and potential subsidies associated with alternative fuels. Environmentally, they consider the sustainability and ecological benefits, such as reduced carbon emissions and improved soil health. Farmers look at how practical it is to use alternative fuels in their farming methods. They consider whether they have the right technology and if training is needed to use it well. This is an important point of view since from this viewpoint, alternative fuels, which are essential in accomplishing the green policy of China to reduce greenhouse gas emissions, manage to accomplish sustainable agriculture and grant energy independence [20]. For example, biodiesel has already shown its potential in farming to minimize carbon footprints and has contributed to improving environmental sustainability. In addition, renewable energy is rewarded by governments through various incentives, hence giving farmers a financial reason to move toward alternative fuels and helping attain both policy goals and farming success. The studies conducted by [21] examined Italian farmers' willingness to invest in multifunctional fully electric battery tractors. They demonstrated that tractor-engine power influences farmers' willingness to adopt electric tractors. A recent study by [22] revealed that Italian farmers were more enthusiastic about utilizing biomethane and electricity than hydrogen. Additionally, they pointed out that the main technical obstacles to widespread adoption were cost and refueling. A study by [23] found that small-scale organic farmers in the USA tend to prefer battery-powered tractors over diesel ones thanks to their perceived environmental friendliness. In addition, they voiced concerns regarding the performance, cost, and maintenance of the system. A recent study by [14] showed that Dutch farmers rated working time, range, operational costs, and purchase costs as the most important attributes of electric tractors, whereas emissions were the least significant barrier to selecting an electric tractor. Furthermore, they pointed out that unfavorable attitudes toward (environmental) policies might impede widespread adoption in the near future.

We identified a gap in the current literature regarding alternative fuel adoption in agricultural applications and developed this research endeavor to fill this gap. A number of earlier studies have examined particular aspects of this subject through the examination of electric tractors, such as those carried out by [21]. Ref. [22] represents the sole study that examines the ranking and adoption barriers of multiple alternative fuels. To date, no comprehensive study has explored farmers' views on alternative fuels as a whole, or the determinants that contribute to their willingness to invest in alternative fuel machinery in the first place. Considering that many tractor models powered by alternative fuels—such as biodiesel, electric batteries, and hydrogen fuel cells—are still under development and

testing, farmers' initial perceptions, attitudes, and cost considerations are critical to any successful adoption of these technologies. Issues such as the dependability/reliability of alternative fuels, refueling infrastructure availability, and long-term maintenance costs are important in the decision-making process. Understanding these factors becomes crucial to predicting the future uptake of alternative fuel machinery in agriculture. The main research question is therefore: what are the underlying factors influencing farmers' intentions to purchase alternative fuel machinery? Thus, ref. [24] emphasized that researching farmers' perceptions and attitudes provides great insights into their cognitive processes, crucial for decision-making about the adoption of innovative agricultural technologies. A model that intricately considers an individual's perceptions and attitudes aligns with two predominant schools of thought within the framework of the theory of reasoned action (TRA): (1) the Technology Acceptance Model (TAM) proposed by [25], and (2) the Theory of Planned Behavior (TPB) outlined by [26]. As TAM and TPB have been used in many studies to predict and understand user perceptions of renewable technology adoption [27,28], it is most appropriate to use them to analyze technology adoption.

The purpose of this study is to combine the TAM and TPB to offer a more comprehensive model for evaluating and buying alternative fuel machinery, such as tractors, combine harvesters, seeders, and tillers. To the best of our knowledge, no comprehensive study has examined farmers' perceptions of alternative fuels in general, and in particular, the factors influencing their inclination to purchase or use alternative fuel machinery. Furthermore, only a limited number of studies investigate farming using alternative-fuel-driven machinery, problems that may occur from the point of view of an eventual implementation perspective, and the correct understanding of farmers' attitudes and perceptions regarding alternative fuel sources. This study tries to fill these gaps by testing variables that may influence farmers' intentions to invest in and adopt alternative fuel machinery, incorporating the conceptual underpinning of the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB). Despite farmers' increased interest in alternative fuels today, the existing literature does not explain what motivates farmers to accept any given technology of these kinds. The present research will try to contribute significantly to the elaboration of effective strategies that could ensure the wide dissemination of alternative fuel machinery in agriculture through the identification of perceived deficits. This dearth is significant because of the dual roles that farmers play as consumers and contributors to alternative fuel markets. Considering the substantial contribution of agriculture to greenhouse gas emissions, understanding farmers' intentions is essential for effectively adopting eco-friendly technologies, such as alternative fuel machinery. Thus, scrutinizing and grasping the causal nexus between the TAM and TPB constructs and farmers' inclination to purchase alternative fuels facilitates the identification of strategies that can facilitate adoption and improve marketing. This study provides new insights into the literature, focusing on the widespread adoption of alternative fuels in agriculture for the first time. The specific focus of this study was to identify the perceived barriers preventing alternative fuels from being utilized in agricultural practices. Additionally, it highlights the farm operations that farmers believe are particularly conducive to the practical implementation of alternative fuel-powered tractors.

The present research is the first of its kind in search of factors that condition farmers' intentions to buy alternative fuels. Both the Technology Acceptance Model and the Theory of Planned Behavior have been extended and applied to farming. Full-time farmers in China were sampled through an online questionnaire in the second quarter of the year 2023. The stratified random sampling method used ensured good representation across regions, farm sizes, and types of agricultural activities. The eligibility criteria include full-time farmers with a minimum of two years of farming experience, presently involved in farming practices and using traditional fuels at the beginning of the study. A total of 281 valid responses were received, which are strongly representative for further data analysis. This study of the combined TAM and TPB models was based on a new use of Partial Least Squares Structural Equation Modeling. Since PLS-SEM manages

complex models with various parts and indicators rather well, and is good for exploratory research, working well to increase the explained variance of the dependent variables, it was the method of choice for this analysis. Unlike traditional covariance-based SEM, PLS-SEM does not place any demands on sample size and normal distribution of data; hence, methodological considerations for PLS-SEM best fit this study. It allows drawing inferences about the direct and indirect relationships among the variables simultaneously with a view to increasing the predictive accuracy and interpretive power of results. It is a very powerful analysis technique used in this study, thus representing the application of PLS-SEM in agriculture and enhancing the methodologies in the respective field. This integrated model is validated by research in terms of its emphasis on empirical observation and measurement of phenomena, hence falling under the positivist paradigm [29]. The study will adopt a positivist approach as it largely entails objective data and quantifiable analysis, which are necessary in testing hypotheses stated in this research work with regard to the reliability and validity of the findings. Unlike interpretivist or constructivist paradigms, which focus on subjective experiences and meanings, positivism offers a structured and systematic framework suitable for the quantitative methods followed in this research. To summarize, this study offers an understanding of the decision-making processes surrounding farmers' adoption of alternative fuels, using theories of technology acceptance and sustainability.

2. Literature Review: Adoption Models and Factors Influencing the Use of Alternative Fuel Machinery in Agriculture

Agricultural technology adoption finds its theoretical underpinnings in seminal works like that of [30]. This long history of adoption studies has been further expounded through conceptual and analytic frameworks such as Everett Rogers' Diffusion of Innovations [31] across a wide range of disciplines, including economics, technology, and public health. These frameworks highlight the complexity of technology diffusion as influenced by perceived relative advantages, compatibility with existing practices, and ease of use [32]. In China, for instance, where agriculture is still pivotal, though highly resource-strained, the shift toward alternative fuel machinery eloquently parallels the transformative impacts of the Green Revolution. This latter initiative was pioneered by Norman Borlaug and sweeping in its impact on farming practices through high-yielding varieties and modern inputs, including fertilizers and irrigation systems, which have substantially improved food production capacity [33]. Similarly, alternative fuel machinery promises to mitigate greenhouse gas emissions and reduce fossil fuel dependency, aligning technological adoption with environmental sustainability. The understanding of this adoption in Chinese agriculture, based on the various dimensions considered for the technology to modify production functions over time due to assimilation by farmers with familiarity and efficiency, was presented by [34]. Such adoption patterns in individual or farm-level scales vary from the single solution adoption of fertilizers to more comprehensive packages involving seeds, fertilizers, and management practices. These patterns reflect the varied adoption dynamics as influenced by farm size, land tenure, access to credit, and socio-demographic factors, such as [35]. Empirical evidence obtained from regions such as Jiangsu, Sichuan, and Hebei suggests that while the initial stages of technology adoption may be slow, the rate increases once the advantages and practicality of the technologies become more apparent as time goes by [36,37]. This study uses the Technology Acceptance Model and the Theory of Planned Behavior to examine how perceived usefulness and social norms, together with barriers such as operational challenges and infrastructure deficits, affect the intention of farmers in China to adopt machinery with alternative fuels. In synthesizing these insights, this research aims to provide actionable recommendations to policy-makers and manufacturers on how best to improve the infrastructure and awareness programs needed to foster a sustainable transition toward alternative fuels in Chinese agriculture. Such an approach would address not only the imperatives of environmental protection but also align with the socio-economic goals of improved productivity and livelihood through technological advancement.

3. Background

3.1. Theory of Planned Behaviour

Ref. [26] proposed the Theory of Planned Behavior, which tries to extend Rational Behavior Theory, focusing on the concept that people engage in a particular behavior because of the rational choice between options available. It also extends the Multi-Attribute Attitude Theory, which tries to understand how attitudes toward certain attributes influence overall behavior. Thus, within this theory, human perceptions are included in explaining these behaviors, which individuals deliberate on and which, at the same time, can sometimes be impulsive or automatic. TPB will, therefore, inform our method of research, embedding the fashioning of our hypothesis into our approach toward data collection and seamlessly fusing theory with empirical analysis. TPB assesses the dynamics of behavioral change, assuming that an individual's behaviors are the result of deliberate planning and intention. It looks at subjective norms, attitudes toward behavior, perceived behavioral control, behavioral intention, and outcomes, and indicates how, as [38] identified, past behavior may alter future intentions. The interplay of past and future behavior is thus the basis of our methodological approach to gaining an understanding of farmers' intent in adopting alternative fuel machinery.

3.1.1. Subjective Norm Hypothesis

A subjective norm refers to the pressure individuals face to engage in or abstain from certain behaviors. These pressures are typically derived from individuals or groups that have a significant influence on individuals' behavior. In other words, people tend to conform to the expectations set by the reference group when making decisions. In general, individuals become more inclined to engage in a behavior when those who are close to them exhibit positive behavior and become less inclined when they are reluctant [39]. A study conducted by [40] indicated that farmers' intentions to decrease fertilizer use were positively influenced by social pressures exerted by family, friends, or influential peers. According to [41], green product purchase intention influences purchasing decisions for green products. Among agroecological technologies, village officials and acquaintances who adopted such practices created a demonstration effect. Consequently, farmers are more inclined to adopt agroecological practices based on their own understanding and assessment [42]. Based on this evidence, we propose the following hypothesis:

H1. *Subjective norms significantly and positively affect behavioral intention to buy alternative fuel machinery.*

3.1.2. Attitude Hypothesis

Attitude can be defined as how one views and assesses a specific behavior in terms of how favorable or unfavorable it is. Farmers' inclination to adopt ecological farming models typically increases when they are more aware of ecological farming technologies and adopt a more positive approach. The lower the subjective inclination towards adopting ecological farming models, the less likely they are to adopt them [43]. A study conducted by [44] showed that attitudes and perceptions toward the use of integrated pest management technologies are likely to be the primary drivers that determine farmers' adoption of these technologies. According to [45], farmers' perceptions are associated with their willingness to adopt abatement technologies. According to their study, heightened perceptions positively influenced the willingness to embrace low-carbon technology, with each incremental increase in perceived capability contributing to a significant adoption rate of 25.5%. Theoretically, it is possible to reap the benefits of implementing eco-agricultural technology. Besides effectively utilizing resources, reducing environmental pollution, and promoting ecosystem advantages, it produces high-quality green products that are pollution-free and characterized by durability. Farmers can benefit from these outcomes in terms of economic prosperity. Therefore, when farmers perceive that alternative fuel machinery can bring positive results, they have a higher willingness to invest in tractors powered by alternative fuels.

H2. *Attitude significantly and positively affects the behavioral intention to buy alternative fuel machinery.*

3.1.3. Perceived Behavioral Hypothesis

Ref. [46] defined the perception of behavioral control as an individual's ability to efficiently grasp resources, influenced by their evaluation of the conditions as well as their own capability. The adoption of rice-shrimp crop technology among farmers is influenced by their own circumstances and the availability of resources. When it comes to evaluating a farm's condition, there are many times in which farmers require specific human resources to embrace rice-shrimp crop technology. Farmers must evaluate their household labor resources before adopting rice-shrimp crop technology to determine if there is surplus labor available for the project. They are evaluated based on their current agricultural production, ensuring that they can leverage their past agricultural experience to mitigate risks and uncertainties while exploring new products. Therefore, the greater the presence of household labor, the more likely it is that a portion of that labor will be devoted to experimenting with these new technologies. Therefore, when farmers perceive that investing in tractors powered by alternative fuels is useful and yields positive results, they are more willing to invest. Therefore, we propose the following hypothesis:

H3. *Perceived behavioral control significantly and positively affects the behavioral intention to buy alternative fuel machinery.*

3.2. Technology Acceptance Model

A significant contribution to the advancement of the agricultural industry is the integration of pioneering methodologies and technologies [47]. Ref. [48] revealed that adopting innovative agricultural practices and technologies leads to increased food safety and production, as well as increased resource efficiency, and environmental stewardship. Among these, a pivotal technological advancement is the development of alternative fuel machinery, which significantly contributes to the sustainability of agriculture. As such, their incorporation does not merely represent an upgrade or replacement of traditional diesel tractors; it signifies a strategic shift towards promoting more environmentally friendly sustainable farming practices. Considering the intersection of technology with sustainability, the integration of the TAM and the TPB offers a robust theoretical framework. In [49], the authors introduced the Technology Acceptance Model (TAM), a psychological theory that summarizes pivotal elements for understanding and forecasting an Individual's use of technology. According to the TAM, attitudes toward behavior significantly influence behavioral intention. Ref. [26] TPB extends the TAM by adding social and control factors that also impact the behavioral intention. According to [26], attitudes toward the target are associated with the evaluated outcomes of behavior, such as intention to use, with individuals with a more positive attitude being more likely to adopt the behavior. TAM introduces two variables, perceived usefulness and perceived ease of use, to explore how technology characteristics might impact behavioral intentions. Ref. [49] describes perceived usefulness (PU) as an individual's belief that a particular technology can improve their performance. As a result of the anticipated advantages that people may gain through technology use, this concept shapes both attitudes and behavioral intentions [50]. However, perceived ease of use measures an individual's perception of how easy it is to utilize a particular technology [49]. With the integration of the TPB, aside from the ideas of the TAM, it also acknowledges that social norms and perceived control are important to change behavioral intentions. Such unification will provide a better understanding of the adoption of technology by farms by joining both the personal views focus emanating from TAM and the social influences and perceived control focuses emanating from the TPB. Contrary to the correlation between perceived usefulness and behavioral intention, the correlation between perceived ease of use and behavioral intention is not always straightforward. However, it is also possible that its impact on behavioral intention is indirect, achieved through the development of attitude and perceived usefulness [50,51]. The combination of the TAM and

TPB highlights that a person's intention affects their actions. It shows that attitudes, social norms, and perceived control work together to form intentions. The ideas of PU and PEOU, created by Davis, are directly linked to intentions. They are also linked to attitudes and affect intentions through TPB's ideas of social norms and perceived behavioral control [52].

3.3. Perceived Usefulness Hypotheses

Perceived usefulness refers to an individual's perception of the benefits that they receive from utilizing a particular technology [49]. Because alternative fuels serve as substitutes for diesel engines, rather than being directly improved by them, it is logical to conclude that potential users will expect a level of performance that is either comparable or superior to that of diesel engines. Additionally, for alternative fuels to be accepted by a wide range of potential users, their costs must be either lower than or equivalent to those of diesel fuel if they are to gain widespread acceptance. Additionally, the driving experience provided by the tractor, which includes aspects such as steering, acceleration, and comfort, should be equal to or better than that provided by diesel-fueled tractors. Thus, we propose the following hypothesis:

H4. *Perceived usefulness significantly and positively affects behavioral intention to buy alternative fuel machinery.*

H5. *Perceived usefulness indirectly affects behavioral intention to buy an alternative fuel using attitude as a mediating variable: the greater the perceived usefulness, the more positive the behavioral attitude, and the stronger the intention to buy.*

3.4. Perceived Ease of Use Hypothesis

Ref. [49] defined perceived ease of use as the degree to which one perceives the ease and simplicity of using a particular technology. A potential alternative to fossil fuels can be found in the form of alternative fuels that offer an environmentally friendly alternative. Furthermore, there is a unique connection between certain alternative fuel production methods and agriculture. Farmers can produce and consume these fuels and by-products. In addition to supporting sustainable value creation, agricultural by-products can be used as fertilizers or animal feed to promote efficient and sustainable resource utilization. Conversely, by-products of fuel production can be used for agricultural purposes such as fertilizers or animal feed. Consequently, considerations regarding both environmental efficacy and overall ease of use of alternative fuels might influence the choice to invest in tractors powered by alternative fuels. Consequently, the following hypothesis was examined:

H6. *Ecological perceived ease of use significantly and positively affects the behavioral intention to buy alternative fuel machinery.*

H7. *Perceived ease of use indirectly affects behavioral intention to buy an alternative fuel using attitude as a mediating variable. The greater the perceived ease of use, the more positive the behavioral attitude and the stronger the intention to buy.*

3.5. Perceived Benefits Hypotheses

According to [53], consumers are more inclined to participate in actions when the benefits outweigh the costs. Ref. [54] showed that while the advantages of renewable energy systems positively influence consumers' attitudes, they have no effect on their intention to adopt these systems. As a result of these significant findings, it is imperative that further investigation be conducted to shed light on the relationship between the perceived benefits of behavioral intentions in different contexts. According to [55], perceived benefits are the primary factor driving LED lighting adoption across the entire sample of consumers, although perceived benefits vary in nature. Furthermore, he found that quality was the most influential benefit shaping adoption intention among low-income households, whereas energy-saving benefits influenced adoption intention among higher-income households. Therefore, based on the above findings, we propose the following hypothesis:

H8. *Perceived benefits will positively and significantly affect behavioral intentions to buy alternative fuel machinery.*

According to [56], consumers' attitudes toward the adoption of sustainable energy technologies are directly affected by perceived benefits, costs, and risks. According to [57], behavioral reasoning theory provides an alternative perspective on mindset and behavior related to the adoption of renewable energy systems. This study identifies the contextual factors that contribute to the adoption of renewable energy systems, such as energy cost savings, environmental benefits, and energy independence. Therefore, the assertion by ref. [58] aligns closely with [55], who found that the factors driving the adoption of LED lighting technologies are likely to be similar to those cited in the assertion. Based on this evidence, we propose the following hypothesis:

H9. *Perceived benefits will positively and significantly affect attitudes towards buying alternative fuel machinery.*

4. Methodology

4.1. Sample and Data Collection

To test the predefined hypotheses within the framework of the TAM and TAB, this study uses a positivist research design that emphasizes empirical observations and measurements (Figure 1). Our approach adheres to the positivist paradigm, which focuses on the systematic collection and analysis of data to validate the theoretical constructs in the context of Chinese agriculture. Therefore, we adopted a survey-based research approach that was appropriate for determining farmers' perceptions and intentions regarding the purchase of alternative fuel machinery. This research utilized a single structured questionnaire to collect data on farmers' perceptions and intentions involving the adoption of ecological agricultural technology. The questionnaire was thus carefully designed based on known constructs from the Technology Acceptance Model and the Theory of Planned Behavior. Each of the constructs was thereafter operationalized through indicators informed by the literature but specifically modified to be about agricultural alternative fuel machinery. The constructs and their respective items include the following: Subjective Norms—SN, with items SN1, SN2, and SN3; Behavioral Attitude—BA with items BA1, BA2, and BA3; Behavioral Control—PBC with items PBC1, PBC2, and PBC3; Perceived Usefulness—PU, with items PU1, PU2, PU3, and PU4; Perceived Ease of Use—PEOU, with items PEOU1, PEOU2, PEOU3, and PEOU4; Behavioral Intention—BI, with items BI1, BI2, and BI3; and lastly, Perceived Benefit—PB, with items PB1, PB2, PB3, and PB4.

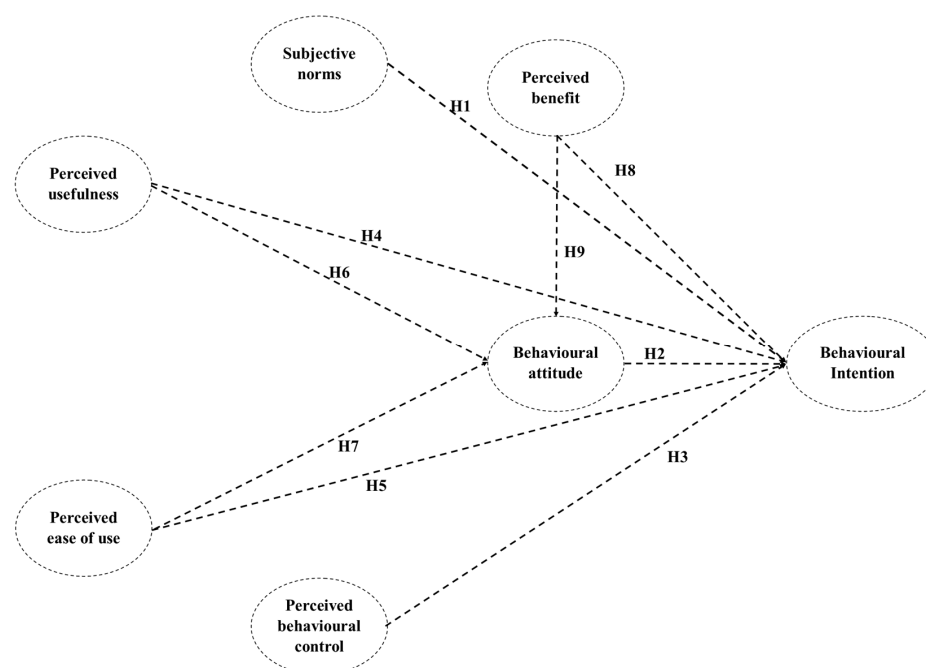


Figure 1. Proposed research model.

The research was conducted in three provinces of China: Jiangsu, Sichuan, and Hebei. The three provinces were selected based on their high agricultural productivity and varying levels of ecological agricultural technology adoption. Jiangsu Province represents the eastern coastal region and is known for advanced farming practices, with some of the highest rates of green technology adoption. Sichuan Province represents the central area; the levels of ecological technology adoption are at a middle level and farming systems have a wide variation. Hebei Province characterizes the northern zone representing the step-by-step integration of ecological agricultural technologies in companies with prominent agricultural undertakings. Figure 2 presents the map showing locations relevant to this work.

In total, 281 full-time agricultural producers participated in this study. For selecting the participating sample, a stratified random sampling technique was utilized in order to ensure representativeness across farm sizes, categories of farming practices, and geographical location of the selected provinces. Sample characteristics included farmers aged between 25 and 65 years, with a mean of 45 years. Farm sizes categorized as small (less than 50 acres) constituted 40%, medium (50–200 acres) constituted 35%, and large (greater than 200 acres) constituted 25%. Agricultural activities comprised 50% crop farming, 30% livestock farming, and 20% mixed farming. This is representative of the demographic structure of the agricultural population in the studied provinces and has only slight deviations from the large-scale farms' population structure. As good as the sample is in representation, there is an issue with the generalizability of the results regarding the cases of livestock farming, since crop farmers are overrepresented. An online survey took place in the first quarter of 2024. An online survey was conducted in 2023. Respondents gave consent to processing anonymous data, and participation was on a completely voluntary basis. Personal contact, social media groups focused on agriculture, and emails to agricultural training farms whose addresses were available online were used as channels to encourage participation. The goals of the study were outlined on the first page of the questionnaire, which can be seen in Table 1 below. The questionnaires consisted of two parts: first, farmers' opinions on 16 statements pertaining to TAM and TPB characteristics were elicited using a 7-point Likert scale, where 1 = highly disagree and 7 = highly agree. The last part of the study was a sociodemographic and farm-related characteristic assessment. A purposeful sampling approach was employed as described by Rahi (2017) to determine the likelihood that full-time farmers in China will invest in alternative fuel machinery in the future. We employed a purposeful sampling approach [59].

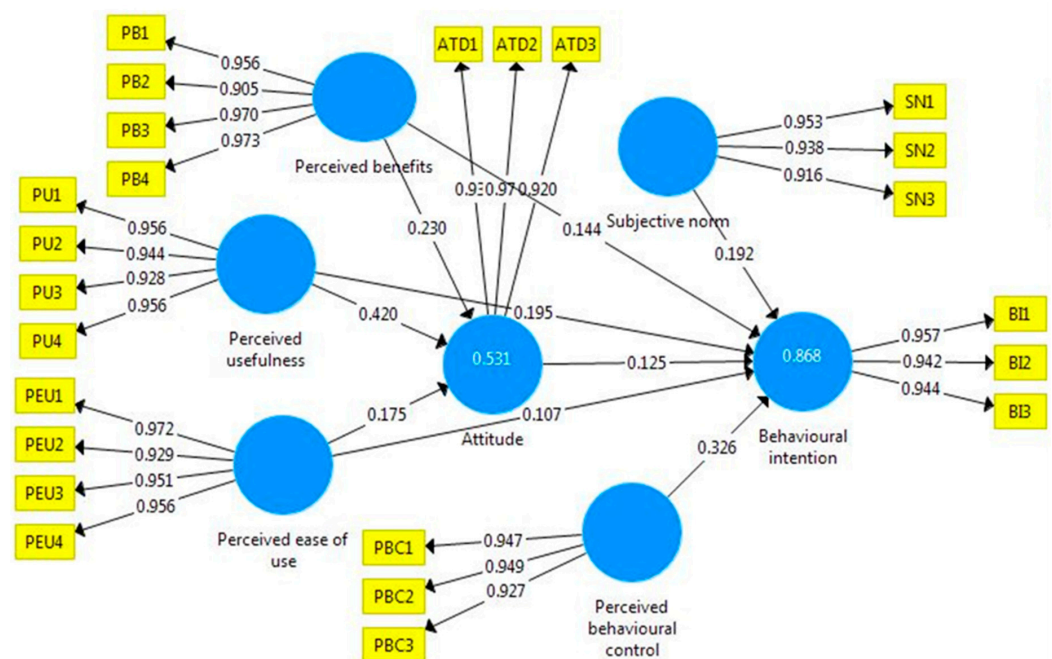


Figure 2. Model with results.

Table 1. Demographic profile.

Demographics	Frequency	Percentage
Age		
<25 Years	44	15.7
25–30	65	23.1
31–40	77	27.4
41–50	41	14.6
>50	54	19.2
Education		
<Bachelor	44	15.7
Bachelor	98	34.9
>Bachelor	139	49.5
Arable land		
<15 ha	72	25.6
15–25	70	24.9
22–40	64	22.8
>40	75	26.7
Agricultural Activity		
Crop Farming	140	50.0
Livestock Farming	84	30.0
Mixed Farming	56	20.0

4.2. Data Analysis

The model hypothesis was scrutinized using structural equation modeling (SEM) with a smart partial least squares approach. The authors of [60] discussed the widespread use of PLS-SEM for data analysis in the business and management domains. Ref. [61] argues that the PLS technique is appropriate for studying cause-and-effect connections. In contrast, ref. [62] found analyzing mediation effects to be more practical. Given the predicted mediation effects of attitudes, PLS-SEM was selected as the best technique for this study. The investigation was divided into two stages: validation of the measurement model, and hypothesis testing.

5. Results

5.1. Common Method Biasness (CMB)

Although the study was based on self-reported data from questionnaires, which may be questionable due to the presence of Common Method Biasness (CMB), several steps were taken to reduce its impact and ensure the validity of the results in this study. The test for CMB—the Harman single-factor test, as provided by [63]—was performed. In this test, all the variables were loaded into a factor analysis to determine if one factor would emerge or if one factor accounted for the majority of the covariance among the variables. Our analysis indicated that a total of 33.43 percent of the variance accounted for by one factor is less than the 40% threshold often cited as indicative of substantial common method variance. As a result, this output would indicate that CMB is not a serious concern in our data. To further strengthen our study design against common method bias, anonymous responses were collected to decrease the influence of any social desirability bias or other response biases involved, should respondents feel their responses could be traced back to them. Also, the questionnaire items had been placed in a strategic random order to reduce a patterned response. This is another methodological precaution against common method bias. A graph showing the distribution of the explained variance by the factors can be included here to make the information more accessible visually and to support our claim concerning the lack of CMB. This will visibly show that the lower variance explained by the first factor does not meet the usual threshold for a significant common method bias, hence demonstrating the reliability of our findings (Table 2).

Table 2. Results of CMB: total variance explained.

Component	Total Variance Explained					
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.433	35.136	35.136	8.433	35.136	35.136
2	2.855	11.895	47.032			
3	2.113	8.806	55.837			
4	1.471	6.129	61.967			
5	1.146	4.773	66.740			
6	1.005	4.189	70.929			
7	0.858	3.575	74.503			
8	0.719	2.996	77.499			
9	0.641	2.670	80.170			
10	0.568	2.366	82.536			
11	0.491	2.047	84.583			
12	0.462	1.925	86.508			
13	0.442	1.842	88.350			
14	0.429	1.787	90.136			
15	0.395	1.645	91.781			
16	0.339	1.411	93.192			
17	0.304	1.265	94.457			
18	0.266	1.108	95.566			
19	0.251	1.044	96.610			
20	0.237	0.989	97.599			
21	0.182	0.757	98.356			
22	0.163	0.679	99.035			
23	0.137	0.572	99.607			
24	0.094	0.393	100.000			

Extraction Method: Principal Component Analysis.

5.2. Measurement Model

The proposed model was subjected to Confirmatory Factor Analysis (CFA) by following the procedure laid down by [64]. To check the reliability and internal consistency of the constructs, we calculated CA and for all the constructs' values were greater than the threshold limit of 0.7, suggesting that the internal consistency of the measures was adequate as per suggestions given by [65]. Estimates of CR also revealed satisfactory scores greater than the threshold of 0.7, proving that the constructs were acceptable. In addition, AVE for all constructs was greater than 0.5, indicating satisfactory convergent validity. Outer loadings for each construct were computed through the PLS algorithm in order to further support the measurement model; we checked that each item was beyond the threshold value of 0.7. Moreover, the procedure followed here was supported by an alternative measure of internal consistency; that is, rho_A proposed by [66]. In our case, all the rho_A values have been above 0.7, thus again supporting the reliability of our measurement model. Therefore, from Table 3, it will be observed that both these tests lend further credence to the reliability and validity of the constructs in our measurement model and offer an overall view of the model's strength.

To demonstrate discriminant validity, we used three methods to demonstrate the differences between measurements of one variable and those of another [67]. Ref. [68] examined the correlation between variables to determine whether they were related to AVE for each hypothesis. As shown in Table 4, each construct possessed acceptable discriminant validity based on the square root of AVE. Further validation was performed using HTMT [67].

Table 3. Construct validity.

Constructs	Items	FL	A	rho_A	CR	AVE
Attitude	ATD1	0.938	0.962	0.962	0.962	0.893
	ATD2	0.976				
	ATD3	0.920				
Behavioral intention	BI1	0.957	0.964	0.964	0.964	0.898
	BI2	0.942				
	BI3	0.944				
Perceived behavioral control	PB1	0.956	0.959	0.959	0.959	0.885
	PB2	0.905				
	PB3	0.97				
	PB4	0.973				
Perceived benefits	PBC1	0.947	0.975	0.975	0.975	0.906
	PBC2	0.949				
	PBC3	0.927				
Perceived ease of use	PEU1	0.972	0.975	0.975	0.975	0.907
	PEU2	0.929				
	PEU3	0.951				
	PEU4	0.956				
Perceived usefulness	PU1	0.956	0.972	0.972	0.972	0.895
	PU2	0.944				
	PU3	0.928				
	PU4	0.956				
Subjective norm	SN1	0.953	0.955	0.955	0.955	0.876
	SN2	0.938				
	SN3	0.916				

Table 4. Discriminant validity.

	ATD	BI	PBC	PB	PEU	PU	SN
ATD	0.945						
BI	0.730	0.948					
PBC	0.616	0.860	0.941				
PB	0.615	0.753	0.678	0.952			
PEU	0.588	0.719	0.641	0.630	0.952		
PU	0.682	0.808	0.733	0.654	0.639	0.946	
SN	0.625	0.800	0.772	0.607	0.594	0.656	0.936
Heterotrait–Monotrait Ratio (HTMT).							
	ATD	BI	PBC	PB	PEU	PU	SN
ATD							
BI	0.730						
PBC	0.616	0.86					
PB	0.614	0.753	0.678				
PEU	0.588	0.719	0.641	0.63			
PU	0.682	0.807	0.733	0.654	0.639		
SN	0.625	0.800	0.772	0.607	0.594	0.656	

5.3. Structural Model

This model reveals several significant relationships. First, there is strong support for the association between attitude and behavioral intention, with a coefficient of 0.125 and a t-statistic of 3.31, indicating a significant positive relationship. Furthermore, perceived benefits had a significant impact on attitudes (coefficient = 0.230, t-statistic = 3.863) and behavioral intentions (coefficient = 0.149, t-statistic = 3.711), suggesting that attitudes and intentions are influenced by perceived advantages. Further, perceived behavioral control positively impacts behavioral intention (coefficient = 0.304, t-statistic = 6.107), suggesting that perception of control affects the intention to engage in certain behaviors. In addition, perceived ease of use significantly impacted attitude (coefficient = 0.178,

t-statistic = 3.102) and behavioral intention (coefficient = 0.113, t-statistic = 2.987), emphasizing the influence of ease of use on attitudes and intentions. High perceived usefulness correlated strongly with both attitude (coefficient = 0.402, t-statistic = 6.501) and behavioral intent (coefficient = 0.198, t-statistic = 4.439), demonstrating the importance of perceived utility in influencing attitudes and intentions. Finally, subjective norms positively impacted behavioral intention (coefficient = 0.192, t-statistic = 4.067), indicating that individuals' perceptions of social pressure impacted their behavior (Table 5). As a result of these findings, it is evident that the hypothesized relationships within the model are robust and that a number of factors influence individuals' attitudes and intentions toward the behavior in question (Figure 2).

Table 5. Structural equation modeling (SEM).

Path	Beta	SD	T Values	p Values	Confidence Interval		Remarks
					5%	95%	
H ₁ : SN → BI	0.192 ***	0.047	4.067	0.000	0.103	0.286	Pass
H ₂ : ATD → BI	0.125 ***	0.038	3.31	0.001	0.058	0.207	Pass
H ₃ : PBC → BI	0.304 ***	0.05	6.107	0.000	0.212	0.403	Pass
H ₄ : PU → BI	0.198 ***	0.045	4.439	0.000	0.109	0.284	Pass
H ₅ : PEU → BI	0.113 ***	0.038	2.987	0.003	0.036	0.18	Pass
H ₆ : PU → Attitude	0.402 ***	0.062	6.501	0.000	0.278	0.528	Pass
H ₇ : PEU → Attitude	0.178 ***	0.058	3.102	0.002	0.045	0.273	Pass
H ₈ : PB → BI	0.149 ***	0.04	3.711	0.000	0.069	0.225	Pass
H ₉ : PB → ATD	0.230 ***	0.059	3.863	0.000	0.111	0.349	Pass

Note. ATD: attitude; BI: behavioral intention; PBC: perceived behavioral control; PB: perceived benefits; PEU: perceived ease of use; PU: perceived usefulness; and SN: subjective norm. *** ($p < 0.001$).

The product coefficient approach technique was used to investigate the mediating role of *EC*, *ER*, and *EK*, and the significance of the indirect impact was determined using bias-corrected bootstrap Confidence Intervals (Cis) [69]. Table 6 shows the mediating role of *ATT* in the relationships between *PU*, *PEOU*, *PB*, and *BI*. *ATT* significantly mediated the relationship between *PU* and *BI* ($\beta = 0.05$, $t = 3.019$, $p = 0.003$), *PB*, and *BI* ($\beta = 0.029$, $t = 2.398$, $p = 0.017$). *ATD* did not significantly mediate *PEOU* or *BI* scores.

Table 6. Mediation results.

Mediation Paths	Beta	SD	T Value	p Value	Confidence Interval		Remarks
					2.50%	97.50%	
Perceived benefits → Attitude → Behavioral intention	0.029	0.012	2.398	0.017	0.011	0.059	Accepted
Perceived ease of use → Attitude → Behavioral intention	0.022	0.01	2.217	0.027	0.006	0.045	Accepted
Perceived usefulness → Attitude → Behavioral intention	0.05	0.017	3.019	0.003	0.024	0.097	Accepted

5.4. The Effect Size and Predictive Relevance

The predictive validity of the overall complex model is computed using the blindfolding method, where a Q^2 value greater than 0 indicates that the model has predictive power and suggests an f^2 value within the threshold that represents a medium effect size [70]. In this regard, the f^2 values for all the relevant relationships are within the cut-off criteria. The respective adjusted R^2 values of *ATD* and *BI* are 0.531 and 0.868, respectively (see Table 7).

Table 7. Effect size and predictive relevance.

Endogenous Variables	R ²	Q ²	Exogenous Variables	Effect Size f ²
Attitude	0.531	0.439	Perceived benefits	0.056
			Perceived ease of use	0.034
			Perceived usefulness	0.183
Behavioral intention	0.868	0.726	Attitude	0.053
			Perceived behavioral control	0.231
			Perceived benefits	0.068
			Perceived ease of use	0.041
			Perceived usefulness	0.1
			Subjective norm	0.1

6. Discussion

The findings of the study align with the core principles of the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB). These models assert that attitudes toward a behavior play an important role in determining a person's intention to perform that behavior. These findings are in line with those from [71], who showed that farmers who hold positive attitudes toward alternative fuel machinery have a considerably higher probability of adopting these technologies. It is logical to conclude that a favorable attitude reflects an assessment of the benefits, ease of use, and overall utility of the technology, making adoption more likely. The perceived benefits of alternative fuel machinery significantly influence farmers' attitudes toward it. Similar to our findings [72], found that farmers are more likely to adopt new technologies when they perceive substantial benefits, such as cost savings, environmental advantages, or increased efficiency. Such consistency in the findings of similar studies underlines the crucial aspect of farmers' perceptions in the adoption of sustainable farming practices. In addition to these perceived benefits, adoption is strongly reinforced by a favorable outlook that reinforces the decision to consider adoption. In addition to influencing attitudes, perceived benefits directly affect behavioral intentions. This suggests that farmers are motivated to adopt technology regardless of their attitude because of the advantages they perceive. Farmers' decision-making relies heavily on tangible benefits to motivate adoption intentions, which is exemplified by the direct effect. In line with the TPB, perceived behavioral control affects behavioral intentions. This result aligns with the findings of [73]. This factor reflects how farmers perceive their ability to control and implement alternative fuel machinery. However, personal experiences and particular competencies among farmers differ greatly, and these affect perceived behavioral control. Farmers with previous experience in handling sophisticated agricultural equipment, for example, perceive their control to be higher and would, therefore, have a greater willingness to adopt new technologies compared to less experienced farmers.

The likelihood of farmers adopting a technology increases if they believe that they have the right resources, knowledge, and opportunities. Consequently, perceived self-efficacy and resource availability are crucial factors in the adoption process. According to TPB, subjective norms have a significant impact on behavioral intentions. This indicates that social influences, such as peer opinions, community leaders, and industry standards, play an important role in shaping farmers' intentions. For instance, the decision of a farmer to adopt machinery using alternative fuels might greatly depend on the endorsement of influential figures within the community or on prevailing practices adopted by other neighboring farms. The social endorsement serves to provide a supportive environment for adoption, and in fact, it has been observed in the study of [74] as relating to subjective norms. Specific manifestations of social influence bear important meaning in the definition of the workings of subjective norms in certain agricultural communities. Such specific examples of social influence are very important in ascertaining how subjective norms work within those particular agricultural societies.

The adoption of alternative fuel machinery is more likely to occur if significant others support or advocate its adoption. This finding agrees with the work of [74], in which the

researchers have shown that decision-making behaviors are influenced by social pressures and norms. Further, the authors of [75] have shown that one's perceived ease of use significantly influences one's attitude. Thus, this agreement further points to the multifaceted aspects that influence decision-making behaviors and further stresses the roles both of society and of personal perception in the formation of attitudes toward new technologies. Based on the TAM, users are more likely to develop a positive attitude toward a technology if it is perceived as easy to use. Machinery with alternative fuels that can be operated with ease would be more acceptable to farmers and thus increase the likelihood of adoption. In addition, perceived ease of use has a direct impact on behavioral intention as it relates to perceived ease of use [75]. This indicates that farmers are motivated to adopt alternative fuel machinery owing to their simplicity and ease of use. Using this finding, we emphasize the need for intuitive and easy-to-integrate technology into existing farming practices to encourage adoption. The TAM is fundamentally influenced by perceived usefulness, which has a strong positive influence on attitude.

Our findings also support the study conducted by [76], which found that a positive attitude toward the adoption of alternative fuel machinery develops when farmers believe it will increase their productivity, efficiency, or profitability. As a result of this high significance, it is clear that perceived usefulness is one of the main factors contributing to positive attitudes. In addition, perceived usefulness influences behavioral intentions. This result was consistent with the findings of [76]. This indicates that farmers are directly encouraged to adopt the technology because of its perceived practical advantages, rather than by forming a positive attitude. The direct relationship between utility and effectiveness illustrates how they drive adoption. Attitude partially mediates the relationship between perceived benefits and behavioral intentions. In addition to directly affecting BI, perceived benefits also indirectly influence BI through attitudes. According to this partial mediation, positive attitudes are formed because of perceived benefits, which further reinforces our intention to adopt new technologies [77]. As a result of this significant mediation, attitudes were strongly implicated in the relationship between perceived usefulness and behavioral intentions. In addition to directly affecting BI, perceived usefulness cultivates positive attitudes, which facilitate adoption intentions. As a result, we are reminded of the importance of perceived usefulness in both direct and indirect pathways that influence adoption intention.

6.1. Theoretical Implications

This study investigated farmers' intentions to buy alternative fuel machinery in China's agricultural industry and yielded several promising theoretical implications. Farmers' behavioral intentions were strongly influenced by attitudes, as indicated by the positive and significant path coefficients of 0.125. These findings indicate the need to foster positive attitudes towards alternative fuel machinery among farmers to increase the adoption of these tractors. Second, both attitude and behavioral intention are strongly influenced by perceived benefits, as evidenced by the path coefficients of 0.230 and 0.149, respectively. This suggests that emphasizing the benefits of alternative fuel machinery, such as cost savings, environmental benefits, and efficiency, might change farmers' attitudes and subsequently, their purchase intention. Third, perceived behavioral control and perceived ease of use significantly predicted farmers' behavioral intentions. The likelihood of farmers purchasing alternative fuel machinery increases when farmers believe that they can control their behavior and they are easy to operate. To promote adoption, practical concerns should be addressed and user-friendly designs and interfaces should be ensured. Further, perceived usefulness was found to be a strong determinant of both attitude and behavioral intention, with path coefficients of 0.402 and 0.001, respectively. To sway farmers' perceptions and intentions positively, alternative fuel machinery must be demonstrated to be practical, effective, and efficient. Furthermore, subjective norms were significantly correlated with farmers' behavioral intentions, with a path coefficient of 0.185. Consequently, farmers' intentions to adopt alternative fuel machinery are influenced by their

social network's perceptions and opinions. Therefore, interventions aimed at supporting social norms and influencing peer groups might be effective in promoting adoption. In general, these findings add to the theoretical understanding of factors influencing farmers' intentions to buy alternative fuel machinery in China's agricultural industry, emphasizing the significance of attitudes, perceived benefits, perceived ease of use, perceived usefulness, perceived behavioral control, and subjective norms in determining adoption behaviors. Using these insights, targeted interventions and strategies can be developed to facilitate the widespread adoption of sustainable agricultural technologies in and beyond China.

6.2. Practical Implications

Farmers' motivation to adopt alternative fuel machinery in the Chinese agricultural setting provides important insights that will be helpful for various agricultural stakeholders. These could be useful in the formulation of policies, agricultural extension services, and business enterprises for promoting strategies in the adoption of sustainable technologies. The positive relationship of attitude with behavioral intention infers that a good attitude toward AEM will result in a significant increase in the probability of adoption. Demonstration strategies for AEM focused on economic viability and ecological stability may be one of the most feasible approaches. Success stories or testimonials from other members of the farming community may be presented as a means for initiating positive attitudes leading to increased adoption. With perceived advantages that include cost reduction and increased efficiency, education that highlights these aspects could potentially influence farmers in terms of attitudes and intentions. In addition, there is a need for training sessions and demonstrations showing that alternative fuel machinery will raise productivity, reduce dependency on old fuels, and be advantageous for environmental concerns, which may help alter perceptions and encourage the adoption of new technology by farmers. Farmers will be willing to use an alternative fuel machine when they perceive that they can access the knowledge, resources, and support that will help them operate the machine. Training programs offering farmers the opportunity to learn technical skills will increase confidence, as will technical support. Likewise, maintenance service and a user manual written in one's native language lessen the intimidation and difficulty of operating such a machine.

The results showed that the use of alternative fuel machines greatly depends on the importance of social influence. Thus, social influence should be positive, in that friends and local leaders should motivate farmers to use alternative fuel machines. Farmers' associations, cooperatives, or networks are also other effective avenues of spreading the advantage of alternative fuel machines where knowledge flows among themselves. Getting important people like community leaders, farm owners, or local farming experts to support and show these technologies could greatly help more people use them. Another important antecedent of intention to adopt is perceived ease of use. In this regard, the operation and maintenance of alternative fuel machinery should be simplified to reduce complexity as a barrier to adoption. Designing user-friendly machinery that would easily fit into the existing way of farming will require top attention from stakeholders in the industry. Moreover, clear, step-by-step guides and follow-up support will help build up farmers' confidence in the use of the technology. Farmers increasingly realize that even though the initial machinery investments are higher for alternative fuels, it will pay off in the long run. Financial barriers can thus be minimized through available government subsidies, tax incentives, or even low-interest loans. It thus is left to the policymakers and agricultural organizations to work with the manufacturers to offer cheaper versions or financial aid packages that attract farmers to invest in alternative fuel technologies. This would therefore suggest that policymakers and agricultural extension services can do much to drive the adoption of alternative fuel machinery, focusing efforts on the factors identified within this present study. These include the provision of education and training programs that can help enhance perceived behavioral control and technological know-how, offering subsidies or other financial incentives to surmount cost barriers, and developing community participation and peer pressure by encouraging endorsement from respected

local ambassadors. Designing user-friendly, low-complexity equipment for integration into existing farming systems and developing outreach programs directed toward communicating the financial, environmental, and operational benefits that accrue to farmers with the adoption of alternative-fuel-powered equipment might have a strong influence in compelling stakeholders to accept sustainable agricultural technologies if considered strategically. This will help to achieve the general aims of modernization and sustainability in China's agriculture.

6.3. Limitations and Future Research Directions

Despite the importance of studying farmers' intentions to buy alternative fuel machinery, it is important to acknowledge their limitations and chart the way forward for future research. In spite of the fact that relationships among variables have provided valuable insight, several factors deserve further investigation. While the current model effectively demonstrates that attitude, perceived benefits, perceived behavioral control, perceived ease of use, usefulness, and subjective norms affect farmers' behavioral intentions, it is crucial to delve deeper into the contextual factors that may moderate or mediate these interactions. The predictive power of the model can be enhanced by understanding the nuances of the cultural, economic, and environmental contexts. Additionally, the study's focus on particular regions or demographics within China may limit its generalizability. Future research could adopt a more comprehensive approach to capture a more representative sample by considering various geographical regions and demographic characteristics. In addition to the specific hypotheses mentioned above, the general hypothesis of this study suggests that farmers' intentions to adopt alternative fuel machinery are significantly influenced by temporal dynamics and decision-making processes. Incorporating longitudinal studies would present how farmers' intentions to adopt alternative fuel machinery vary over time, thereby providing information on the durability of temporal changes in behavioral intention. Such qualitative methods as interviews and focus groups will provide a more subtle understanding of the processes that influence farmers' decisions. These approaches supplement the quantitative findings with rich qualitative details about the decision-making processes of farmers. Exploring all these avenues further in the future can lend robustness and applicability to the research findings; therefore, more effective strategies for encouraging the adoption of alternative fuel machinery in China's agriculture are likely, which also embody values like inclusiveness, comprehensiveness, and sustainability.

7. Conclusions

The current study investigated the factors that influence the motivation of farmers to adopt machinery using alternative fuels in agriculture in China. Surprisingly, the results have shown that farmers' positive attitudes toward machinery are effective in motivating them to buy the machinery. The relationship recorded between attitude and behavioral intention was very good: $ATD \rightarrow BI: \beta = 0.125, p < 0.001$. However, this relationship has to be interpreted carefully, considering other exogenous factors like market forces or government policies that may also interact with the purchase behavior of farmers. While perceived benefits are a significant contributor, attitudes also explain much of the variance in the intention to adopt; hence, these external factors should be considered so as not to overgeneralize the relationship. Perceived benefits were identified as one of the major drivers, directly influencing both attitude ($PB \rightarrow ATD: \beta = 0.230, p = 0.002$) and behavior intentions ($PB \rightarrow BI: \beta = 0.149, p < 0.001$). However, despite perceived benefits featuring as one of the most important drivers, they are by no means the only component involved in driving the adoption process forward. Attitudes, influenced by a variety of cognitive and context-specific factors, play a key role in the adoption process. Although these advantages seem quite clear, high capital costs and unfamiliarity with the technology could slow down broad diffusion. Identification of this sort of constraint tends to provide an improved perspective on the adoption process. Notably, attitude partially mediates the association between perceived benefits and behavioral intentions, as from $PB \rightarrow ATT \rightarrow BI$, the path

coefficient is 0.230 and the significant p -value is 0.000, reflecting attitudes important to the farmers in making their decisions, not just merely taking benefits into consideration.

Other important variables include perceived ease of use, which has a great influence on attitude and behavioral intention directly: $PEU \rightarrow ATD: \beta = 0.178, p = 0.002$; $PEU \rightarrow BI: \beta = 0.113, p = 0.003$. This result may be different because farmers' experiences and skill levels might help form perceptions about perceived ease of use. Indeed, future research should also take into consideration individual variability—experience and proficiency, for instance—in the processing involved, vis-a-vis perceived ease of use and mastery.

The other key element is perceived usefulness, which has a significant effect on attitude and behavioral intentions: $PU \rightarrow ATD: \beta = 0.402, p < 0.001$, and $PU \rightarrow BI: \beta = 0.198, p < 0.001$, therefore confirming the role played by the Technology Acceptance Model. All these considerations, however, should be assessed in specific agricultural contexts, as differences in technological accessibility and infrastructure can change the magnitude of the impact perceived usefulness would be able to cause. Subjective norms also played a leading role in that societal pressures influenced farmers' choices as far as adopting the technology was concerned. Therefore, $SN \rightarrow BI, \beta = 0.192, p < 0.001$. The interaction between social networks and community interactions may also be worth investigating further for their adoption decisions, as peer and local influences presumably varied across the different regions. The concept of perceived behavioral control (PBC) was found to have a significant influence on behavioral intentions ($PBC \rightarrow BI: \beta = 0.304, p = 0.000$), highlighting the importance of farmers' confidence in their capability to utilize the technology effectively. Nonetheless, the disparities in farmers' skill levels and their proficiency with the technology may lead to varying effects on their intentions to adopt it. This finding implies that subsequent research should explore the impact of individual differences on decisions regarding adoption.

Overall, the findings indicated that farmers are cautious adopters of alternative fuel machinery, driven by perceived benefits, ease of use, usefulness, social norms, and behavioral control. However, full recognition must be given to external factors, like government policies and market mechanisms, which might also drive these adoption decisions. Apart from this, the study of the regional and individual differences in adoption will add to the holistic understanding of the adoption process. This will be fundamental information for policymakers and producers who are interested in promoting sustainable agricultural practices in China. Future research should address the shortcomings identified and also include contextual aspects that would more widely impact the landscape of adoption.

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