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Behavioral precursors in the innovation-decision process: the case of bioenergy in Ethiopia

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Abstract

Despite ample potential energy sources, most developing countries depend highly on fuelwood to meet their energy needs, with repercussions on the environment and human health. Bioenergy innovation is one way to combat this issue, the adoption rate of which remains low in many of them. Using primary data collected from Ethiopian experts in the energy field, this study combines factor analysis with ordered logit regression to identify the drivers of introduction and diffusion of bioenergy innovations. Moreover, this study detects and analyzes the behavioral precursors of the respondents' intention to adopt brand new or upgraded bioenergy innovations. The results reveal differences between their decision-making processes and suggest targeted research and policy strategies to boost the adoption rate of bioenergy innovation.

Keywords: innovation, bioenergy, behavior, decision-making, Ethiopia

1 Introduction and conceptual background

Energy is a fundamental resource for any economic system and of strategic significance for developing countries whose economies are starting to take-off. Moreover, widespread access to clean and affordable energy improves environmental quality and individuals' well-being. However, despite ample potential for energy production, most developing countries depend highly on fuelwood to meet their energy needs. This dependence has severe repercussions for eco-systems, including deforestation, land degradation [1], and biodiversity loss, as well as indoor air pollution and high rates of mortality and morbidity [2]. Thus, considering the negative effects on the quality of life and climate change, there is an urgent need for sustainable energy-related innovations[1] [4,5,6]. Addressing this need requires careful consideration of challenges and opportunities affecting the adoption of feasible solutions and the exploitation of local renewable sources. On the one hand, efforts should be made to improve the efficiency and sustainability of currently deployed technologies, e.g., by introducing eco-compatible biomass or ameliorated tools in the energy generation process. On the other hand, strategies should be designed to create an environment for entrepreneurs, investors, and other stakeholders that is conducive to the adoption of radical innovation and smart energy systems [7,8]. Accordingly, this study aims at identifying and analyzing the major factors affecting the adoption and diffusion of both these two types of bioenergy innovations in Ethiopia and refers to bioenergy as the energy generated from renewable and sustainable biological sources.

In the past two decades, the Ethiopian government has launched several energy generation projects to meet domestic demand. However, only 23% of the total population currently has access to electricity [9]. Moreover, there is a huge energy access divide between the country's urban and rural areas. Specifically, while 87% of the urban population has access to electricity, only 5% of the rural population is connected to an electrical grid [9]. Indeed, Ethiopia's energy sector is highly dependent on biomass (firewood, charcoal, crop residues, and animal dung) that accounts for 89% of the national total energy consumption in 2010 [10,11]. As such, millions of women and children in rural areas devote their time collecting fuelwood for domestic functions (e.g., food cooking and lighting [12]), while the urban poor spend a sizable amount of their income on their daily energy needs [13]. Imported petroleum is an alternative power source in Ethiopia, accounting for 7% of total energy use, while an important and growing source is represented by the hydropower generation [14].

[1] For example, Gebreegziabheret al. [3] shows that the diffusion of improved cooking stoves has the potential to save around 1,400 ha per year from deforestation in Ethiopia.

Nevertheless, the rising demand for fossil fuel due to population and economic growth forces the country to allocate a large portion of its financial reserves to import oil, negatively affecting the trade balance and level of pollutant emission. Introducing sustainable bioenergy technology can be one of the prime solutions to the country's growing energy demand, providing widespread energy access for both urban and rural households. However, like other developing countries, the adoption rate of modern, clean, and sustainable energy technology in Ethiopia is low [3,15,16]. Thus, it is crucial to analyze the determinants that can hinder or boost the deployment and propagation of bioenergy innovation in rapidly evolving economies such as Ethiopia.

Several factors are influencing the choice to adopt sustainable (bioenergy) innovation [17]. Among these, Kabir et al. [18] find that socio-economic conditions, such as educational level, strongly influence the decision to adopt novel bioenergy technologies in Bangladesh; Pine et al. [19] show that awareness of health conditions is the main factor that affects the adoption rate of modern improved biomass stoves in Mexico, and Sovacool [20] identifies the effect of public-private partnership in diffusing renewable energy services. Together with contextual, technological, and economic determinants, studies confirm the importance of behavioral precursors affecting the decision-making process [21,22,23]. These behavioral precursors are significant when the choices are repetitive and deal with vital resources as in the case of the energy-related decisions. For instance, agents might develop positive or negative preferences for new solutions as a result of their propensity for perceived challenges and opportunities (e.g., time and risk preferences), their knowledge and awareness of innovation-related outcomes, or social pressures [24,25,26]. Behavioral precursors represent an essential leverage for supporting innovation-oriented motivations and decisions. Accordingly, policy interventions aimed to increase the adoption rate of new energy solutions should take into due account these factors. However, there is limited evidence on the behavioral precursors that drive the adoption of novel, environmentally friendly technologies [27,28,29]. Since the individual and situational diversity implies an array of behavioral patterns [30,31,32], when addressing the choice to adopt a new energy solution (especially in developing societies), it is important to study the decision-making process by differentiating between categories of adopters and between types of innovations [22]. Indeed, agents may have specific preferences when coping with a brand new or an upgraded technology. This affects the aggregate rate of innovation adoption, thus of energy access, in a society. According to the innovation diffusion theory [33], new technology dissemination depicts an S-shaped curve where only a few adopters in the early stage invest in the innovation, while other agents take time to choose. This raises the question of what factors influence individuals to adopt an upgraded (ameliorative) innovation instead of a newly available one. Regarding the types of innovations, this study categorizes new bioenergy solutions in to brand new (i.e., radical) and upgraded (i.e., improved) innovation based on whether the innovation is yet to be introduced in the target community (e.g., waste-to-energy plants) or comes with a new feature enhancing the performances of already-implemented tools and systems (e.g., more efficient cook stoves). This enables distinguishing between adopters with a high propensity to deploy a brand new bioenergy technology (BNT) and adopters oriented toward an upgraded bioenergy technology (UBT)[2]. By detecting the behavioral precursors driving the adopters' innovation-decision processes for the two types of innovations, this study provides behavior-centered insights relevant to the introduction and diffusion of new bioenergy technologies in Ethiopia. These goals are achieved by analyzing cross-sectional primary data from a survey of 95 Ethiopian stakeholders, using both factor analysis (FA) and ordered logit methodologies. The results reveal that the respondents' intentions to adopt a BNT are related with specific external conditions (i.e., factors supporting and hindering the behavioral performance) and with the expected environmental benefits (i.e., favorable attitude toward the consequences of the choice). Differently, the motivations to adopt an UBT are negatively affected by a lack of knowledge of the innovation's public benefits (i.e., weak attitude), but positively associated with the social referents' judgments (subjective norms). The remaining part of this study is structured as follows: section 2 describes the theoretical framework, focusing on the selected behavioral model. Section 3 provides insights on the methodological approach; section 4 presents the results; and, finally, section 5 provides discussion and concludes with some policy implications.

2 Theoretical model of behavior and specific research objectives

Different economic and psychological models aim to explain human behavior when deciding to adopt innovation [34,35]. For instance, the subjective expected utility models assume that decision-makers are rational, selfish (thus focused on their payoff), and efficient users of fully available information sets. According to these models, when choosing an option the agents reliably identify, evaluate, and compare all attributes of feasible alternatives. However, theoretical constructs and empirical evidence show that agents' decisions often deviate from this standard scheme [23]. Since judgments are comparative,

[2]Throughout this study, the terms intention, motivation, and preference are considered synonymous, and so are the terms of behavioral precursor and behavioral antecedent.

individuals contrast the real option with their personal expectation ("similarity judgments," [36]), thus resorting to heuristics and incurring systematic biases [25]. In particular, evidence shows that when dealing with a choice inherently associated with uncertainty and framed as a gain (such as the bioenergy innovation-decision this study analyzes), people tend to display risk-averse behavior. This raises two questions. First, to what extent can the contextual conditions influence this aversion and explain the deviation of the agents' actual decision from the standard model? Second, which other behavioral precursors (e.g., attitudes and abilities) contribute to the low adoption rates of cost-effective technologies? To address these questions, recent studies have identified some behavioral factors, such as social influence and individuals' awareness of environmental benefits [18,22,37,38] that systematically affect agents' decision to adopt green technologies.

By referring to alternative behavioral models such as the Theory of Planned Behavior (TPB, [39]), this study analyzes behavioral precursors that account for different levels of propensity for bioenergy innovation (Figure 1). The TPB is a socio-psychological model that is largely adopted in different fields of behavioral analysis, such as environmental psychology [40,41,42] and innovation diffusion [43]. The TPB does not assume decision-makers' rationality, but describes the human behavior as the result of a structured process derived from a series of cognitive determinants (behavioral precursors). Unlike the standard model that infers the decision-making process from observed behavior, the TPB analyzes the process by directly assessing its constitutive elements. According to the TPB, an individual's decision is a function of the *intention* to engage in the behavior, i.e., the motivation is the immediate antecedent of the performable action and measures the interest in the option [22,30]. In turn, the individual's intentions are assumed to depend on specific precursors: *attitudes, subjective norms, and perceived behavioral control*; which are considered distant predictors of the behavior.

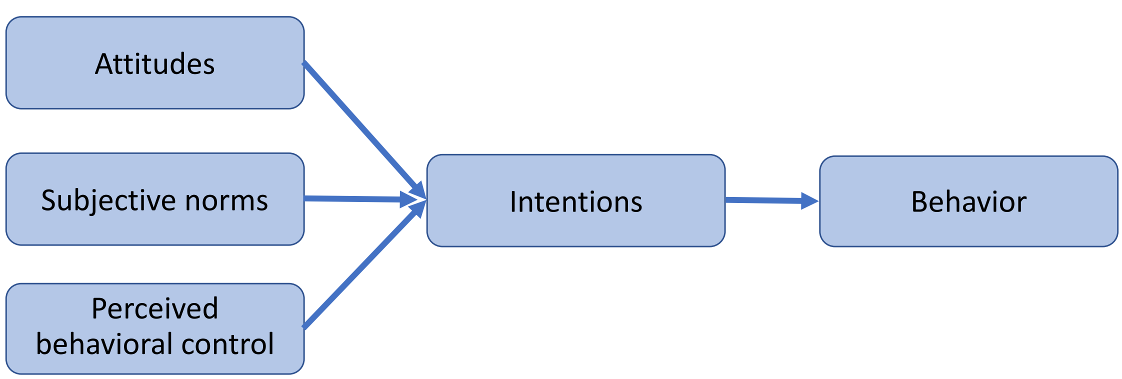

Figure 1- The Theory of Planned Behavior - TPB (source: [39]).

Attitudes express beliefs and evaluations of positive or negative thoughts (i.e., knowledge) and feelings (i.e., awareness and moral norms) about the possible consequences of performing the behavior. In this study, attitudes are elicited by the knowledge and awareness of the expected outcomes of adopting a bioenergy innovation. Specifically, these outcomes include the assessed profitability of the innovation and the considered healthy and environmental benefits the technology can generate in terms of improved individual and community's quality of life and reduced level of pollutant emissions.

Subjective norms (the second behavioral precursor affecting the individual's intentions) are determined by the social customs and judgments on the considered behavior and its implications (descriptive and injunctive norms, i.e., what the social referents such as customers and citizens do or approve, respectively [24]). We derive the subjective norms from the respondents evaluation of what the others do (i.e., imitation) or think (i.e., social acknowledgment and collaboration with customers as measure of their opinion) about the bioenergy-oriented choice.

The third antecedent of the motivations is the perceived behavioral control that refers to the individual's evaluation of the opportunities and challenges affecting the performance of the behavior. In this study, the control factors concern both the decision-makers' skills and abilities to deploy and manage the new technology as well as the external conditions (e.g., availability of feasible technologies and relational resources) facilitating or interfering with the decision to adopt the innovation. Therefore, we measure the accessibility to public financing, the capacity to design relevant organizational strategies, the availability of solutions provided by the research, and the collaboration with foreign universities to study the relationship between the respondents' perceived behavioral control and their intention to adopt the bioenergy innovations.

This study derives a behavioral segmentation of Ethiopian experts based on their intention to introduce alternative bioenergy innovations with different risk levels, and, according to the TPB, directly measures the related behavioral precursors through surveyed evaluations of the main obstacles and drivers affecting the decision. The survey is designed to test whether there is an asymmetry between the adopters' decision-making processes as defined by the following research hypotheses:

- the intention to adopt a BNT is significantly affected by extrinsic (situational) conditions (i.e., the perceived behavioral control);
- the intention to adopt an UBT is significantly affected by intrinsic (individual) factors (i.e., their attitudes).

The first hypothesis is based on the assumption that adopters of a BNT are in general eager to try a new solution or more likely to be open-minded, and possess abilities and skills [33] that enable them to exploit the possible economic, environmental, and social benefits that sustainable technologies can provide. Therefore, adopters' strong intention to use a brand new innovation is more likely affected by contextual factors such as collaboration with research centers and access to cutting-edge bioenergy technologies. By contrast, adopters of an UBT are assumed to react weakly to technological innovations; thus, their intention to adopt a new bioenergy solution is expected to be affected by an inadequate knowledge and awareness of the possible outcomes the performable behavior can produce.

3 Methodology

3.1 Sampling and data collection

Purposive sampling technique was used to select and recruit the respondents among the local experts[3] active in the energy sector in Addis Ababa and Mekelle cities, Ethiopia. Addis Ababa is the capital of Ethiopia and by far the largest city, while Mekelle is a Northern large city with flourishing bioenergy sector. The two cities were chosen because they include various representative experts with direct and grounded experience in the energy domain. Moreover, the sample was aimed to include entrepreneurs who actively deal with innovation-centered decisions in the energy sector including entrepreneurs from agriculture, processing industries, and energy services as well as private and public operators (e.g., consultants and extension services), and policymakers. The experts were selected by local university partners, contacted at their local address by enumerators, and invited to the local universities (Addis Ababa University, and Mekelle University) to participate in the survey.

The primary data were collected using a pre-validated self-administered questionnaire submitted in October, 2015, and in December, 2015, in Mekelle and Addis Ababa, respectively. Respondents participated as representative of their organizations, were briefly introduced by the enumerators about the questionnaire that even included questions specific to their organizations, and provided with clarifications whenever they raise concerns. The questionnaire includes four sections, and it aims to measure the respondents' evaluations about the different topics using an ordinal scale ranging from 1-9. In the first section, experts are required to assess their level of interest in adopting the two types of bioenergy innovations (i.e., BNT and UBT). The second and third sections focus on the respondents' opinion on the obstacles and drivers affecting the introduction of bioenergy innovation (19 obstacles and

[3] Throughout this study, the terms experts and respondents are used interchangeably.

14 drivers: Table A.1 and A.2, respectively), while the fourth section deals with the main factors motivating the diffusion of innovation (15 determinants: Table A.3). These last sections are designed to elicit respondents' behavioral precursors associated with the adopters' intention to introduce the bioenergy innovation.

A major limitation of the survey is the relatively small sample size due to the limited number of experts in the energy field in Ethiopia despite the focus on the two leading areas of the country. Nonetheless, this study provides specific information on the decision-making process concerning the adoption of new bioenergy solutions and also offers relevant insights to researchers and policymakers regarding orientation of or support for technological changes. A second limitation is the lack of information on the socio-demographic characteristics (i.e., age, gender, ethnicity, and education) of the respondents. We refrained from asking such detailed questions, as respondents would be less likely to participate in the survey. Nevertheless, a few questions, such as respondents' sector or organization size, were included. Unfortunately, the response rate was very poor and not sufficient to be reported in this study. However, according to the TPB, these attributes "are considered background factors," affecting the individual preferences and behavior "only indirectly," with their effect captured by the behavioral precursors this study analyzes [39]. A third limitation is the possibility that respondents reveal high interest in both the innovations (brand new and upgraded). For this particular class of respondents, it is challenging to associate their subsequent responses (e.g., lack of knowledge) directly to BNT or UBT. In this study, this was the case for a few respondents (8%) that were classified as BNT adopters. Finally, it was not feasible to disentangle the respondents' personal opinion from the interest of their organization/community.

3.2 Data analysis

This study implements a two-phase data analysis using Stata/SE 15.0 to analyze the main determinants of the bioenergy innovation process and to identify the relevant behavioral patterns affecting the innovators' decision-making. First, similar to Akimoto et al. [44], this study conducts an exploratory FA to achieve a better understanding of the general obstacles and drivers that influence the introduction and diffusion of new bioenergy-centered solutions in Ethiopia. Factors with eigenvalue greater than one are retained in the model. Second, ordered logit estimations are drawn to detect the major behavioral precursors fostering or inhibiting the local adopters' choice when facing prospective bioenergy alternatives and the related risks and opportunities. With reference to the FA, the methodology determines core unobservable factors (i.e., the continuous latent variables F_j, [45]) explaining the variance and correlations of a large set of observed variables [46,47]. Two tests are applied to check the robustness of the developed FA models: Bartlett's test of sphericity that enables rejecting the hypothesis that the variables are uncorrelated (1% of significance level), and the Kaiser-Meyer-Olkin (KMO) test for sampling adequacy that measures the data suitability for the FA. In this study, the determinants (i.e., obstacles and drivers) of the introduction and diffusion of bioenergy innovation are described by the manifest variables (x_i) that FA groups into latent factors (F_j), as in the following linear function:

$$x_i = \beta_{i0} + \beta_{i1}F_1 + \beta_{i2}F_2 + \beta_{i3}F_3 + \cdots + \beta_{ij}F_j + \varepsilon_i \quad (1)$$

where β_{ij} represents the factor load for each x_i, and ε_i the error term.

After extracting the general factors F_j affecting the possible evolution of the Ethiopian bioenergy sector, this study develops two ordered logit regression models to scale down the analysis to the behavioral precursors of the individual innovation-decision process. The related outcome variables are defined by the respondents' intention to adopt a new bioenergy technology (i.e., BNT or UBT). In particular, three possible degrees mirror their self-evaluated level of preference for the proposed two types of innovations. If the respondent's intention to adopt the innovation is higher than the 75th percentile (between the 75th and 50th percentiles, or below the 50th percentile), then the underlying motivation is assumed strongly (moderately, or weakly) oriented toward that type of innovation. Afterward, the intention to deploy the two types of innovations is regressed on explanatory variables (x_i) derived from the set of the respondents' evaluations (Appendix A: Tables A.1 and A.2). Finally, the significant variables elicited (x_i) are associated with the corresponding behavioral antecedents (attitudes, subjective norms, and perceived behavioral control) for each of the two types of innovations. From this behavioral perspective, the general regression model is expressed by (2):

$$Z_{B,U} = \alpha_{B,U} + \delta_{B,U} attitude + \gamma_{B,U} subjective\ norm + \theta_{B,U} perceived\ behavioral\ control + \varepsilon_{B,U} \quad (2)$$

where $Z_{B,U}$ represents the respondents' intention to adopt a brand new or an upgraded bioenergy innovation, respectively, while δ, γ, and θ are the coefficients of the explanatory variables, i.e., the behavioral antecedents of the related innovation-decision process. Moreover, in order to ease the interpretation, the odds ratio is computed and discussed. The Brant test of parallel regression assumption is applied to test the proportional odds assumption. Finally, a robustness check is conducted by developing logit models as alternative estimation techniques (Appendix B).

4 Results

The results achieved through the FA and the ordered logit models are based on the evaluations made by a sample of 95 experts who completed the questionnaire. The respondents are local experts in the energy field such as entrepreneurs (7 respondents), private and public consultants (64), and policymakers (12); while the remaining subjects (12) belong to other professional profiles. About a half of the respondents (51%) show a high or medium level of interest in adopting a BNT, whereas the equivalent share for the UBT is about 64%. In general, traditional societies are more likely to have low interest in adopting innovations. This generally weak propensity to adopt an innovation suggests an expected low acceptance rate for new, sustainable bioenergy solutions in Ethiopia. This leads to the hypothesis that the potential adopters may face numerous obstacles affecting their choice to deploy new technologies (e.g., limited financial support, risk aversion, and lack of knowledge of the bioenergy domain) that are not counterbalanced by adequate motivations or supportive conditions. This hypothesis finds confirmation in the respondents' evaluation on the barriers to and drivers of the introduction of bioenergy innovation. Table 1 shows that inadequate contributions from research and development (R&D), and lack of access to information on bioenergy innovations are identified as the major obstacles to the innovation adoption. Moreover, the lack of knowledge of environmental and public benefits, the limited access to public financial facilities, the unavailability of skilled manpower, and risk aversion are the additional obstacles the respondents recognize. Table 2 describes the drivers favoring the introduction of bioenergy innovation. Accordingly, the increasing energy demand and the interest to reduce the GHGs emissions stand out as the main fostering factors. Moreover, the respondents assign a high score to the contribution the bioenergy technologies make to the environmental safeguard and to the quality of life.

Table 1–Obstacles to the introduction of bioenergy innovation.

Variables	**Mean**	**Standard deviation**
Unavailable qualified staff	7.213	2.475
Low benefit/cost ratio	6.122	2.282
Risk due to technology	7.044	2.490
Risk due to market conditions	5.573	2.536
Limited access to private financing	7.032	1.919
Limited access to public financing	7.114	2.385
High fiscal burden	5.096	2.320
Lack of information on bioenergy innovations	7.626	1.998
Lack of knowledge of environmental benefits	7.315	2.133
Lack of knowledge of public benefits	7.088	2.274
R&D not addressing the business' needs	7.692	2.096

Table 2–Drivers of the introduction of bioenergy innovation.

Variables	Mean	Standard deviation
Energy demand	8.424	1.584
Financial support to investments	6.903	2.152
R&D	6.315	2.320
Contribution to quality of life	7.600	1.675
Contribution to environmental quality	7.739	1.809
Reduction of GHGs emissions	8.022	1.852
Social acknowledgment	6.289	2.062
Collaboration with providers/technical assistants	6.360	1.872
Collaboration with customers	7.611	1.852
Collaboration with other enterprises	6.663	1.719
Collaboration with institutions	6.791	1.895
Collaboration with local universities	6.870	1.974
Collaboration with foreign universities	6.912	2.045
Economic return	7.022	1.671
Social responsibility	7.750	1.867

Table 3 below shows the respondents' perception of the main drivers contributing to the diffusion of the bioenergy innovation across the community/country. The increasing demand of energy access and use in Ethiopia emerges as the most important incentive for spreading the new bioenergy technologies.

Table 3–Drivers of the diffusion of bioenergy innovation.

Variables	Mean	Standard deviation
Growing of energy demand	8.143	1.495
Entrepreneurs' imitative willingness to change	7.444	1.742
Human resources (skills)	7.264	1.744
Contribution to quality of life	7.620	1.568
Contribution to environmental quality	7.789	1.434
Reduction of GHGs emissions	7.978	1.866
Social acknowledgment	6.270	2.071
Social responsibility	7.386	2.136
Organizational strategies	7.500	1.762
R&D	7.045	1.930
Social norms and local partners	6.747	1.881
Social norms and foreign partners	6.886	1.991
Policy incentives (subsidies, fiscal deductions)	6.580	1.843
Public investments (infrastructures)	6.591	1.740
Private investments	6.056	1.879
Credit availability	6.932	2.105

4.1 Behavioral precursors of the adoption of bioenergy innovations: FA and regression results

This section aims at detecting and analyzing the behavioral precursors of the bioenergy-oriented innovation-decision process. Firstly, from a general perspective the FA elicits the overall obstacles and drivers associated with the introduction and diffusion of bioenergy innovations. Secondly, a distinction between types of innovations and between adopters is made and specific regression models are developed so at to identify the behavioral precursors underlying the intention to adopt a BNT and an UBT.

4.1.1 Behavioral precursors in the innovation decision-making process: FA results

The rotated factor matrix in Table 4 lists the factor loadings for the first FA model concerning the assessed obstacles to the introduction of bioenergy innovation in Ethiopia, namely the lack of knowledge and the (limited) financial facilities. Based on the modeled linear combination of the observed variables, these two factors explain the 43% of the total variance of the respondents' evaluations of obstacles to innovation adoption.

✓ The first factor, knowledge and risk (F1.1, at 33%), reveals how much the respondents value the full understanding of the innovation's effects in their decision-making. Limited access to information on technological issues, and possible environmental and public benefits, as well as the gap between public R&D and business' needs hinder the introduction of modern bioenergy solutions in the country. In addition, the risk related to the new technology is moderately associated with F1.1. This prime obstacle (the lack of knowledge of the innovation's opportunities, thus the lack of awareness of the implications for the society) limits the strength of the behavioral beliefs (the capacity to link choice and its outcomes), thus feeding (from a TPB perspective) unfavorable attitudes toward the decision to adopt the innovation.

✓ The second factor, (limited) financial facilities (F1.2, at 9.6%), relates to the difficulties in obtaining affordable capitals for investment purposes (i.e., limited access to private and public financing).

These two obstacles (F1.1 and F1.2) show that individual behavioral attitudes (i.e., uncertainties related to the innovations, and knowledge of the outcomes the decision produces) prevail over the situational and operational concerns (i.e., financial and fiscal conditions affecting the agent's behavioral control) in the decision-making process dealing with the choice to introduce bioenergy innovation in Ethiopia.

Table 4– Obstacles to the introduction of bioenergy innovation.

Variable	KMO	Communality (share of variance)	Factor1.1 'knowledge and risk'	Factor 1.2 'financial facilities'
Unavailable qualified staff	0.845	0.291	0.455	0.29
Low benefit/cost ratio	0.834	0.269	0.454	0.25
Risk due to technology	0.689	0.264	0.514*	0.007
Risk due to market conditions	0.807	0.376	0.363	0.494
Limited access to private financing	0.663	0.569	0.004	0.754**

Limited access to public financing	0.804	0.562	0.318	0.679*
High fiscal burden	0.632	0.22	0.107	0.457
Lack of information on bioenergy innovations	0.831	0.542	0.687*	0.265
Lack of knowledge of environmental benefits	0.828	0.695	0.746*	0.372
Lack of knowledge of public benefits	0.738	0.639	0.797**	-0.06
R&D not addressing the business' needs	0.793	0.303	0.507*	0.213
No of variables			11	11
Eigenvalue			3.67	1.06
Variance (extraction capacity)			2.84	1.89
Total variance explained (%)			0.33	0.096
Cumulative variance (%)			0.33	0.43

Note: Bartlett's test of sphericity:chi square=296.35;df= 55; P-Value= 0.0000;KMO = 0.78 Factor loadings (i.e., measures of the relationship between the observed variable and the factor F) with value > 0.75 (**), 0.75-0.5 (*), and 0.5-0.3 are considered "strong," "moderate," and "weak" loadings, respectively.

The second FA model, based on the respondents' assessments of the innovation-decision drivers, identifies two main factors that explain the 57.8% of the total variance: networking and environmental concern (Table 5).

✓ The first factor, networking (F2.1, at 49%), emerges as the major driver of innovation introduction in Ethiopia emphasizing the necessity for potential adopters to establish collaborations with institutions and other operators. Specifically, the results suggest that these interrelationships should be dual-goal oriented and include collaborations with research centers and universities (to acquire knowledge in choosing and deploying the new bioenergy solution), and various technical-support services provided by public and private organizations (to develop skills and ability necessary to manage the innovation, while limiting the inherent uncertainty). In addition to the collaboration with relevant stakeholders, the "economic return" and "financial support to investments" variables also show a high correlation with F2.1.

✓ A positive attitude toward new bioenergy solutions is detected by the second factor, environmental and socio-economic concerns (F2.2, at 8.8%), that outlines the adopters' consideration for the sustainability of the outcomes (e.g., increased environmental quality, reduction of emissions, improvement of the quality of life, and meeting the energy demand) [49] the envisaged innovation can produce.

Table 5–Drivers of the introduction of bioenergy innovation.

Variable	**KMO**	**Communality (share of variance)**	**Factor 2.1 'networking'**	**Factor 2.2 'environmental and socio-**

				economic concerns'
Energy demand	0.865	0.491	0.369	0.596*
Financial support to investments	0.818	0.483	0.621*	0.312
R&D	0.768	0.666	0.816**	0.025
Contribution to quality of life	0.846	0.534	0.246	0.688*
Contribution to environmental quality	0.888	0.691	0.298	0.776**
Reduction of GHGs emissions	0.865	0.588	0.218	0.735*
Social acknowledgment	0.772	0.295	0.325	0.435
Collaboration with providers and technical assistants	0.807	0.524	0.688*	0.225
Collaboration with customers	0.799	0.633	0.324	0.727*
Collaboration with other enterprises	0.896	0.689	0.674*	0.484
Collaboration with institutions	0.902	0.744	0.792**	0.343
Collaboration with local Universities	0.889	0.782	0.811**	0.353
Collaboration with foreign Universities	0.882	0.666	0.694*	0.43
Economic return	0.908	0.345	0.538*	0.236
Social responsibility	0.896	0.534	0.234	0.692*
No of variables			15	15
Eigenvalue			7.345	132
Variance (extraction capacity)			4.633	4.03
Total variance explained (%)			0.49	0.088
Cumulative variance (%)			0.49	0.578

Note: Bartlett's test of sphericity: chisquare= 935.5;df=105; P-Value=0.0000; KMO= 0.86
Factor loadings (i.e., measures of the relationship between the observed variable and the factor F) with value > 0.75 (**), 0.75-0.5 (*), and 0.5-0.3 are considered "strong," "moderate," and "weak" loadings, respectively.

Regarding the main drivers of the diffusion of bioenergy innovation across the country, the third FA model identifies two main factors (external conditions and social motivations) that explain 54.8% of the total variance (Table 6).

✓ The first factor, external conditions (at 45%), gathers a series of contextual variables that foster the innovation propagation and is mainly attributable to public policies supporting the adopters' investment choice (incentives and investments, F3.1). Together with these measures, a set of situational conditions are identified as additional determinants of the innovation diffusion such as the availability of private financing, accessibility to R&D findings, and professional skills. These elements (policy measures and contextual conditions) enhance the innovators' capacity and limit the investment risks, making the adopters' behavioral performance (perceived behavioral control) the crucial behavioral antecedent affecting the innovation diffusion.

✓ Moreover, FA identifies socio-economic motivations (F3.2, at 9.8%) as another driver of innovation propagation. This factor links together environmental, economic, and social evaluations (from GHGs reduction to imitation) that in the experts' opinion can motivate the entrepreneurs' decision to adopt the bioenergy innovation, thus contributing to its diffusion.

Table 6–Drivers of the diffusion of bioenergy innovation.

Variable	KMO	Communality (share of variance)	Factor 3.1 'external conditions'	Factor 3.2 'socio-economic motivations'
Growing of energy demand	0.866	0.386	0.26	0.564*
Entrepreneurs' imitative behavior willingness to change	0.812	0.65	0.329	0.736*
Human resources(skills)	0.868	0.579	0.673*	0.354
Contribution to quality of life	0.878	0.599	0.345	0.693*
Contribution to environmental quality	0.83	0.649	0.17	0.787**
Reduction of GHGs emissions	0.867	0.568	0.039	0.753**
Social acknowledgment	0.828	0.425	0.405	0.511*
Social responsibility	0.823	0.578	0.27	0.711*
Organizational strategies	0.941	0.488	0.512*	0.476
R&D	0.852	0.619	0.737*	0.276
Social norms and local partners	0.903	0.545	0.616*	0.406
Social norms and foreign partners	0.814	0.475	0.61*	0.322
Policy incentives (subsidies, fiscal deductions)	0.82	0.506	0.704*	0.101
Public investments (infrastructures)	0.804	0.601	0.756**	0.17
Private investments	0.852	0.633	0.781**	0.151
Credit availability	0.887	0.391	0.534*	0.326
No of variables			16	16
Eigenvalue			7.16	1.57
Variance (extraction capacity)			4.53	4.16
Total variance explained (%)			0.45	0.098
Cumulative variance (%)			0.45	0.548

Note: Bartlett's test of sphericity: chi square= 854.17;df=120; P-Value= 0.0000; KMO = 0.852
Factor loadings (i.e., measures of the relationship between the observed variable and the factor F) with value > 0.75 (**), 0.75-0.5 (*), and 0.5-0.3 are considered "strong," "moderate," and "weak" loadings, respectively.

The results of the three FA models detect different behavioral precursors influencing the innovation-decision process. On the one hand, the weak individual attitude towards new bioenergy solutions (caused by the lack of knowledge, thus of awareness of the consequences that the choice can generate) negatively affects the motivations to adopt the innovation. On the other hand, the adopters' perceived behavioral control proves to be the major behavioral driver of innovation introduction and diffusion. This ability to perform the behavior is recognized not just as an individual quality the adopter innately possesses, but also as a resource that strongly depends on two different contextual conditions. With reference to innovation introduction, the individual capacity to deal with new solutions stems from the collaboration with institutions and other operators. Regarding the innovation diffusion, the adopters' perceived behavioral control relies on targeted supporting policy measures. The emerging difference between these two phases of the innovation adoption path stresses the opportunity to further investigate the behavioral precursors that characterize the decision to adopt a BNT or an UBT, separately.

4.1.2 Behavioral precursors of the intention to adopt a BNT and an UBT: regression results

The main variables that challenge and/or drive the adoption of the two types of bioenergy innovations are identified by developing two distinct ordered logit models, and analyzed from a behavioral perspective. According to the assumed research hypotheses, the results of this study confirm that the intention to adopt a BNT is mainly and significantly correlated with extrinsic conditions (the perceived behavioral control and subjective norms), whereas the intention to adopt an UBT is mainly and significantly correlated with intrinsic factors such as the individual's attitude toward new technological solutions and their outcomes. Moreover, the results also suggest that more complex interactions between specific behavioral precursors characterize and further differentiate the two innovation-decision processes. For the sake of completeness, the results include both the odds ratios and the regression coefficients. Throughout this study, the odds ratio compares the probability of high intention versus the combined middle and low intention to adopt the considered innovation.

4.1.2.1 Intention to adopt a BNT

Based on the results of the first ordered logit model, the intention to adopt a BNT is regressed against a series of contextual determinants (Table 7). Specifically, the related odds ratios (column 3) show that the probability of a high level of intention to adopt a BNT increases as the *availability of R&D* advancements improves, the potential of *reduction of GHGs emissions* increases, and the opportunities of establishing a *collaboration with the consumers* become concrete. Therefore, three main determinants motivating the innovation-oriented behavioral performance are identified. First, the contribution that a BNT can offer to the environmental quality is significantly and positively associated with the favorable attitude to adopt it[4]. Second, the access to cutting-edge technologies (perceived behavioral control) is a reliable factor directly linked to the motivation to introduce a BNT. Third, the direct relationship with the closer stakeholders (i.e., the customers: subjective norm) can further contribute to orienting the decision toward a BNT-centered investment.

On the contrary, the *social acknowledgement* (i.e., the overall approval or disapproval of the society for an innovative solution: subjective norm) is significantly but negatively associated with the intention to adopt a BNT. Accordingly, the odds ratio indicates a link between the social rejection of new technologies and the innovators' propensity to introduce a BNT. This antagonistic behavioral precursor reveals a gap between the mainstream idea of energy access and use in the Ethiopian society (focused on providing/gaining access to conventional, traditional sources, thus on a general lack of knowledge of modern, sustainable energy opportunities) and the innovators' open orientation toward the bioenergy-centered innovations.

Table 7–Behavioral precursors of the intention to adopt a brand new bioenergy technology (BNT).

Variables	Coefficient	Std. Err.	Odds Ratio	P>z	95% Confidence Interval		Behavioral precursors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lack of information on bioenergy innovations	-0.04	0.221	0.961	0.857	-0.472	0.393	
Lack of knowledge of public benefits	0.025	0.165	1.025	0.879	-0.298	0.348	
Reduction of GHGs emissions	1.163**	0.535	3.198	0.03	0.114	2.211	Attitude
Organizational strategies	-0.264	0.18	0.768	0.143	-0.618	0.089	
Collaboration with customers	0.648**	0.288	1.912	0.025	0.083	1.213	Subjective Norm
R&D	0.893***	0.253	2.442	0	0.397	1.389	Behavioral Control
Limited access to public financing	0.017	0.168	1.017	0.919	-0.312	0.346	
Collaboration with foreign universities	0.092	0.26	1.097	0.722	-0.417	0.602	
Social acknowledgment	-0.49**	0.235	0.613	0.037	-0.95	-0.03	Subjective Norm
cut1	16.39***	5.189	16.39		6.222	26.56	

[4]Similarly, Kang et al. [50] identify the climate change issues (such as the emission reduction) as the major driving factors for the bioenergy introduction in Asia.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
cut2	18.4***	5.303	18.4		8.011	28.8	
Likelihood ratio chi square	44.03						
P-Value	0.000						
N	71						
Pseudo R Squared	0.295						

Note: Brant test of parallel regression assumption: chi square= 7.61; P-Value=0.574. The dependent variable is a categorical variable with three levels that describes the intention to adopt a brand new innovation. All the independent variables are considered as continues variables. Column (1) shows the coefficients of the ordered logit estimation; (***), (**), and (*) indicate statistical significance at the 1%, 5%, and 10% level, respectively. Column (2) shows the associated standard errors. Column (3) shows the odds ratio. Column (4) describes the p-values of the estimated coefficients. Column (5) and (6) show the 95% lower and the upper confidence intervals respectively. Column (7) associates each significant explanatory variable with a behavioral precursor.

4.1.2.2 Intention to adopt an UBT

The results of the second regression model reveal a specific and composite set of significant variables and of related behavioral precursors that explain the intention to introduce an UBT (Table 8). A first group of variables concerns the outcomes the adoption of an UBT is expected or not to produce. On the one hand, the UBT *contribution to quality of life* shows a positive correlation with the propensity for its deployment and the odds ratio suggests that the probability of this decision increases as the envisaged effect is valued. On the other hand, the *lack of knowledge of public benefits* displays a negative correlation with the motivation to adopt an UBT as the odds ratio proves (the higher the unawareness of the positive externalities generated by the innovation, the lower the probability of a high level of intention to adopt UBT). Moreover, the *reduction of GHGs emissions* results negatively associated with the preference for the UBT and the related odds ratio indicates that as the individuals' concern for the climate change increases, their intention to adopt an UBT decreases. This first group of explanatory variables describing the evaluation of the effects that an UBT can generate at individual level (quality of life) or miss at societal level (public benefits and reduction of emissions), respectively, highlights the role that the favorable/unfavorable attitudes play as behavioral precursors in this innovation-decision process.

A second group of variables significantly associated with the UBT-oriented decision involves the relationships with other stakeholders. Specifically, the *collaboration with foreign universities* as well as the *collaboration with customers* show a positive significant correlation with the intention to adopt an UBT. Coherently, the related odds ratios indicate that the probability of a high level of this intention to innovate increases as the synergies with the academic world and the sympathy with the economic referents (i.e., market-oriented considerations) improve. These two variables focused on the collaborations the innovators can establish suggest that the intention to adopt an UBT is further associated with the precursors behavioral control and subjective norms, respectively.

Table 8–Behavioral precursors of the intention to adopt an upgraded bioenergy technology (UBT).

Variables	Coefficient	Std. Err.	Odds Ratio	P>z	95% Confidence Interval		Behavioral precursors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lack of information on bioenergy innovations	0.136	0.27	1.146	0.615	-0.394	0.666	
Contribution to quality of life	1.333***	0.431	3.793	0.002	0.488	2.179	Attitude
Lack of knowledge of public benefits	-0.78**	0.319	0.457	0.014	-1.409	-0.157	Attitude
Reduction of GHGs emissions	-1.45***	0.434	0.235	0.001	-2.299	-0.599	Attitude
Organizational strategies	0.043	0.157	1.044	0.782	-0.264	0.35	
Collaboration with customers	1.197***	0.412	3.31	0.004	0.389	2.006	Subjective norm
R&D	-0.08	0.255	0.925	0.761	-0.578	0.423	
Limited access to public financing	0.04	0.163	1.041	0.807	-0.279	0.358	
Collaboration with foreign universities	0.903***	0.313	2.467	0.004	0.289	1.517	Behavioral control
Social acknowledgment	0.299	0.221	1.349	0.175	-0.134	0.732	
cut1	10.38***	3.343	10.38		3.824	16.93	
cut2	12.93***	3.475	12.93		6.115	19.74	
Likelihood ratio chi square	49.07						
P-Value	0.000						
N	70						
Pseudo R Squared	0.32						

Note: Brant test of parallel regression assumption: chi square= 9.14; P-Value=0.519.The dependent variable is a categorical variable with three levels that describes the intention to adopt an upgraded bioenergy innovation. All the independent variables are considered as continuous variables. Column (1) shows the coefficients of the ordered logit estimation; (***), (**), and (*) indicate statistical significance at the 1%, 5%, and 10% level, respectively. Column (2) shows the associated standard errors. Column (3) shows the odds ratio. Column (4) describes the p-values of the estimated coefficients. Column (5) and (6) show the 95% lower and the upper confidence intervals .Column 7 associates each significant explanatory variable with a behavioral precursor.

As alternative estimation technique aimed at testing the robustness of the two developed ordered logit models, this study implements two additional logit models[5]. The first logit model confirms that *R&D, reduction of GHG emissions,* and *collaboration with customers* are significantly and positively correlated with the adoption of a BNT in line with the main findings, with the only exception for *social acknowledgement* that results not significant (Appendix B: Table B.1). Similarly, the second logit model

[5]In the logit models, the outcome variable is a binary variable (0, 1) with value 1 describing the respondent's interest to adopt the innovation when it is greater than the medium value.

shows estimations consistent with the main obtained results except for the variables *lack of knowledge of public benefits* and *collaboration with foreign universities,* which are not significantly correlated with the intention to adopt an UBT (Appendix B: Table B.2). In general, while only few variables do not emerge as explanatory regressors in the logit models, the robustness check validates the main significant results achieved through the ordered logit models that prove to be comparatively more performing in fitting the observations.

5. Discussion and Conclusions

This study relies on data collected from local experts belonging to the energy or related sectors in two areas of Ethiopia, and implements a two-step approach to investigate their intention to adopt alternative bioenergy innovations. First, the FA models detect from a general perspective the overall factors affecting the introduction and diffusion of new bioenergy technologies. Second, we separately look at the decision-making processes guiding the introduction of two different types of bioenergy innovations: specifically, the ordered logit models identify the main behavioral precursors of the individuals' motivations to adopt brand new and upgraded bioenergy innovations.

Three main orders of findings are achieved through the FA. First, the lack of knowledge stands out as the major factor explaining the total variance of the respondents' evaluation of obstacles in introducing bioenergy innovation. From a TPB perspective, the lack of knowledge of the technological innovation and its opportunities feeds unfavorable attitudes towards the decision to adopt the innovation. Second, the results indicate that networking is the most important driving factor of bioenergy innovation introduction in Ethiopia. The two conditions that networking embodies–R&D and collaboration with public bodies–reveal the attention that the adopters pay to the operational issues the innovation introduction implies. Thus, the current capacity to deal with the innovation adoption (i.e., the perceived behavioral control) emerges as the decisive behavioral precursor of the related decision-making process. Third, regarding the experts' evaluation of the main drivers favoring the diffusion of the bioenergy innovation in Ethiopia, a set of situational variables are identified such as the availability of private financing and public supports, the accessibility to R&D findings, and the presence of adequate professional skills. These elements (expressed by the factor "external conditions") are expected to enhance the innovators' capacity and limit the investment risks, and confirm the crucial role that the perceived behavioral control plays as behavioral antecedent of the decisions enabling the innovation diffusion.

As per the distinction between the two types of bioenergy innovations, the regression results show that the behavioral antecedents associated with the individuals' intention to adopt a BNT and an UBT let emerge differences in the related innovators' decision-making processes. On the one hand, general contextual conditions matter to the adoption of a BNT. Specifically, the innovators' propensity toward a BNT is linked to the availability of cutting edge technologies and to the expected reduction of global pollutants emission. On the other hand, more specific contextual conditions as well as idiosyncrasies are crucial to the intention to adopt an UBT. In fact, the motivations generating this decision are positively correlated to the collaboration with the customers and to the outcomes achievable at small scale level (contribution to the community's quality of life), whereas the UBTs are considered ineffective when the benefits are evaluated at large scale (e.g., reduction of GHGs). Moreover, the individual knowledge and awareness of the implications that this type of innovation envisages are relevant to the UBT-oriented innovators' choice. This dichotomy leads to two orders of considerations. First, the behavioral precursors of the individual decision-making process are combined with situational conditions that differ according to the type of bioenergy innovation the adopter evaluates. Second, BNTs characterized by notable good environmental performances are more likely to be attractive for potential innovators.

On the basis of the achieved findings the following main implications and energy strategies can be drawn:

- ✓ the adverse individual attitude toward the bioenergy innovations and, specifically, the lack of knowledge and awareness about the outcomes they generate are the primary obstacle to their introduction. The regression results reveal that this behavioral precursor is crucial when the choice concerns the adoption of an UBT. The results show that the weak attitude the potential adopters manifest suffers from an inadequate information on the functioning of the technological innovation, thus from an insufficient understanding of the deriving public benefits and positive environmental externalities. This cultural obstacle in the innovation-decision process requires an adequate dissemination of information on the nexus between bioenergy and sustainability by implementing training initiatives (e.g., technical educational programs and lifelong learning programs) targeting local operators;
- ✓ the behavioral control factors are decisive in facilitating the innovation-oriented choices, which are conditioned by the collaboration with other actors. In this regard, the results identify the universities/research centers as the essential sources of new technological solutions and know-how, the service providers and consultants for the technical assistance, the public institutions for their role in shaping favorable external conditions, and the other enterprises for creating synergies and sharing

risks. Networking is the main driver that can heighten the behavioral performances in the bioenergy innovation realm. The adopters' need to set up innovation-centered interrelationships calls for university and public policies that include the creation/enhancement of targeted structures (e.g., extension services and new decision-making bodies together with producers' associations) and the implementation of tailored tools (e.g., smart systems and social events);

- ✓ the adopters' innovation-decision processes reveal different behavioral patterns in function of the technological characteristics of the bioenergy solution taken into consideration. Prospective research and policy strategies aimed at supporting the adoption of BNTs should consider the relevant underlying behavioral precursors focusing on R&D efforts, bridging the gap between research and business, and giving priority to the environmentally friendly solutions. Differently, strategies oriented toward the introduction of UBT-centered innovations should aim at building the adopters' abilities and capacity to deploy and manage the innovative technologies, ensuring their operability and scalability, and increasing the knowledge of the social benefits these solutions can generate.

One has to be cautious when interpreting these results because of the following limitations. This study used a relatively small sample size, and it assumes that the role of socio-demographic characteristics is captured (as "background factor") by the behavioral precursors. Therefore, it is a viable avenue for future research to adopt large sample size, and explicitly measure the socio-demographic effects on the bioenergy innovation adoption decision. Moreover, this study associates the identified variables with the TPB behavioral precursors. However, there is a need for further research to directly investigate these behavioral precursors through other appropriate approaches and methodologies (e.g., behavioral economics experiments).

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Appendix A–Description of variables

Table A.1–Description of the obstacles to the introduction of bioenergy innovation.

Variables	Description
Unavailable qualified staff	Difficulties to find qualified staffs in the local market to develop products or assist activities in bioenergy.
Competition with food	The potential risk related to cultivating land for biomass instead of crops.
Low benefit/cost ratio	Lower net benefit/economic return from bioenergy investment.
Risk due to technology	Potential risk related to lack of knowledge of the technology to generate energy from biomass.
Risk due to market conditions	Risk perception related with local demand for bioenergy product and or producers competition.
Limited access to private financing	Difficulty to get financial support from private financial sectors to invest on bioenergy.
Limited access to public financing	Difficulty to get financial support from public financial sectors to invest on bioenergy.
High fiscal burden	High tax rate.
Lack of information on bioenergy innovations	Imperfect information/knowledge on new/upgraded bioenergy innovations.
Lack of knowledge of environmental benefits	Imperfect knowledge on environmental benefit derives from bioenergy innovations.
Lack of knowledge of public benefits	Imperfect knowledge on the public benefits derives from modern bioenergy innovation. for example improvement of society's living standard.
R&D not addressing the business' needs	Research and development activities not addressing the needs of the enterprises.

Table A.2–Description of the drivers of the introduction of bioenergy innovation.

Variables	Description
Energy demand	An increasing of energy demand in the study area.
Financial support to investments	A potential financial support to invest on bioenergy.
R&D	Supports from research and development institutions
Contribution to quality of life	Contribution of the innovation through improving community's quality of life.
Contribution to environmental quality	Intention to improve environmental quality.
Reduction of GHGs emissions	The contribution of the innovation through reducing of CO2 and such emissions released from traditional energy sources.
Social acknowledgment	Obtaining social acknowledgment.
Collaboration with providers and technical assistants	Availability of collaboration with technology (bioenergy innovation) suppliers and technical assistant providers.
Collaboration with customers	Existence of collaboration with customers.
Collaboration with other enterprises	Collaboration with other enterprises such as private firms that are investing on bioenergy innovations.
Collaboration with institutions	Collaboration with other institutions such as public organizations that have positive influence to introduce bioenergy innovations.
Collaboration with local Universities	Existence of direct link with local universities that can share knowledge and resources related to the innovation.
Collaboration with foreign Universities	Existence of collaboration with foreign research institutions and foreign universities that shares their knowledge and resource about the innovation.
Economic return	Profitability of bioenergy innovation investment.
Social responsibility	A responsibility to improve well-being of the society.

Table A.3–Description of the drivers of the diffusion of bioenergy innovation.

Variables	Description
Growing of energy demand	An increasing of energy demand.
Entrepreneurs' imitative behavior or willingness to change	Behavior of entrepreneurs (availability to change, willingness to change, imitation).
Human resources(skills)	Availability of skilled man power.
Contribution to quality of life	An interest to improve wellness of the local community.
Contribution to environmental quality	An intention to improve environmental quality.
Reduction of GHGs emissions	An interest to reduce emission from traditional energy source.
Social acknowledgment	An interest to obtain social acknowledgment as the result of diffusing the technology.
Social responsibility	a responsibility to improve social well-being.
Organizational strategies	Clearly defined vision/strategies, established norms for innovation promotion.
R&D	Availability of research and development activities to solve problems related with the innovation diffusion.
Social norms and local partners	Availability of social capital and local partnership.
Social norms and foreign partners	Existence of social capital and foreign partners.
Policy incentives (subsidies, fiscal deductions)	Incentives such as subsidy and fiscal deduction.
Public investments (infrastructures)	Availability of infrastructure such as road, telecommunication.
Private investments	Availability of private investors in the bioenergy sector.
Credit availability	Availability of financial facilities.

Appendix B–Robustness analysis

Table B.1–Logit model: factors affecting the intention to adopt a BNT.

Variables	Coefficient	Std. Err.	P>z	95% Confidence Interval		Behavioral precursors
	(1)	(2)	(3)	(4)	(5)	(6)
Lack of information on bioenergy innovations	0.092	0.253	0.717	-0.404	0.588	
Lack of knowledge of public benefits	-0.03	0.201	0.863	-0.429	0.359	
Reduction of GHGs emissions	1.237**	0.587	0.035	0.0868	2.388	Attitude
Organizational strategies	-0.29	0.195	0.142	-0.67	0.096	
Collaboration with customers	0.565*	0.33	0.087	-0.082	1.211	Subjective Norm
R&D	0.648***	0.251	0.01	0.1567	1.139	Behavioral Control
Limited access to public financing	0.101	0.178	0.569	-0.248	0.45	
Collaboration with foreign universities	-0.1	0.278	0.718	-0.645	0.444	
Social acknowledgment	-0.43	0.286	0.13	-0.993	0.127	
Constant	-15	5.347	0.005	-25.47	-4.51	
Likelihood ratio chi square	28.08					
P-Value	0.0009					
N	71					
Pseudo R Squared	0.2856					

Note: the dependent variable describes the intention to adopt a BNT. It is a binary variable (0,1) with value 1 when the respondent's intention to adopt the innovation is greater than the medium value. All the independent variables are considered as continues variables. Column (1) shows the coefficients of the logit estimation; (***), (**), and (*) indicate statistical significance at the 1%, 5%, and 10% level, respectively. Column (2) shows the associated standard errors. Column (3) defines the p-values of the estimated coefficients. Column (4) and (5) show the 95% lower and the upper confidence intervals respectively. Column 6 shows the behavioral precursors category of statistically significant variables.

Table B.2–Logit model: factors affecting the intention to adopt an UBT.

Variables	Coefficient	Std. Err.	P>z	95% Confidence Interval		Behavioral precursors
	(1)	(2)	(3)	(4)	(5)	(6)
Lack of information on bioenergy innovations	-0.12	0.319	0.702	-0.746	0.502	
Contribution to quality of life	0.748*	0.441	0.09	-0.117	1.612	Attitude
Lack of knowledge of public benefits	-0.44	0.333	0.187	-1.092		
Reduction of GHGs emissions	-0.85**	0.428	0.048	-1.684		Attitude
Organizational strategies	0.047	0.175	0.79	-0.297		
Collaboration with customers	0.928**	0.426	0.029	0.093	1.763	Subjective norm
R&D	-0.08	0.285	0.771	-0.643	0.476	
Limited access to public financing	0.165	0.183	0.368	-0.194	0.524	
Collaboration with foreign universities	0.494	0.302	0.102	-0.098		
Social acknowledgment	0.318	0.244	0.191	-0.159	0.796	
Constant	-7.59	3.787	0.045	-15.02	-0.17	
Likelihood ratio chi square	26.44					
P-Value	0.0032					
N	70					
Pseudo R Squared	0.2937					

Note: the dependent variable describes the intention to adopt an UBT. It is a binary variable (0,1) with value 1 when the respondent's intention to adopt the innovation is greater than the medium value. All the independent variables are considered as continues variables. Column (1) shows the coefficients of the logit estimation; (***), (**), and (*) indicate statistical significance at the 1%, 5%, and 10% level, respectively. Column (2) shows the associated standard errors. Column (3) defines the p-values of the estimated coefficients. Column (4) and (5) show the 95% lower and the upper confidence intervals respectively. Column 6 shows the behavioral precursors category of statistically significant variables.

Appendix C–Sample of the questionnaire of bioenergy innovation in Ethiopia

The questionnaire you are kindly asked to answer is focused on the diffusion of innovation in the agro-energy sector. A number of stakeholders interested in the energy sector have been asked to participate in the same interview.

This interview is anonymous. The information you provide will not affect your right to any services you are receiving or may receive from the government.

Please provide an answer for each of the following questions:

- In the case of **Section 1** you should choose your profile;
- In the case of **Section 2** (if you selected the profile "entrepreneur") you should indicate the number of employees of your company and the business sector;
- For **Sections from 3 to 6** you should mark the most appropriate answer where:
  1 = not relevant
  9 = extremely relevant

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1. Your profile									
Expert / researcher (researcher, consultant)									
Policy maker / civil servant of “non-research” public institutions									
Expert of “non-research” private institutions (e.g. association)									
Entrepreneur (farmer, manager, etc.)									
Other (please specify)									
2. If you have selected the category “entrepreneur” could you									
Please indicated the number of employee of the farm/enterprise you are running/working for?	0 - 4	5 - 9	10 - 19	20 - 49	50 - 99	100 - 199	200 - 249	250 - 499	> 500
Please indicate your business sector									
3. What kind of innovation of the bioenergy domain (energy from renewable bio-sources) is more interesting for your Company and/or community and/or country?									
Organizational innovation (e.g.: new forms of internal and/or external collaborations)	1	2	3	4	5	6	7	8	9
Incremental biomass and / or bio-energy product (amelioration to an already existing product)	1	2	3	4	5	6	7	8	9
Radical innovation of biomass and / or bio-energy product (development of a new product)	1	2	3	4	5	6	7	8	9
Incremental biomass and / or bio-energy process innovation (amelioration to an already existing process)	1	2	3	4	5	6	7	8	9
Radical biomass and / or bio-energy process innovation (introduction of a new process)	1	2	3	4	5	6	7	8	9
Other kind of innovation (please specify):	1	2	3	4	5	6	7	8	9
4. what are the major obstacles to the introduction of bioenergy innovation?									
Resources availability (land, water, …)	1	2	3	4	5	6	7	8	9
Ethical reasons (i.e. risk for food security due to food vs fuel competition)									
Difficulties to identify qualified staff	1	2	3	4	5	6	7	8	9
Potential competition with food crops	1	2	3	4	5	6	7	8	9
High cost - benefit ratio (low economic return)	1	2	3	4	5	6	7	8	9
High perceived risk due to financial conditions	1	2	3	4	5	6	7	8	9
High perceived risk due to technological availability	1	2	3	4	5	6	7	8	9
High perceived risk due to market variability	1	2	3	4	5	6	7	8	9
Difficulties to obtain private financial support	1	2	3	4	5	6	7	8	9
Difficulties to obtain public financial support	1	2	3	4	5	6	7	8	9
High fiscal burden (heavy taxation)	1	2	3	4	5	6	7	8	9
Difficulties to reorganize the production process	1	2	3	4	5	6	7	8	9

Lack of information on innovative solutions / technologies	1	2	3	4	5	6	7	8	9
Lack of clear knowledge on the deriving environmental benefits for your area	1	2	3	4	5	6	7	8	9
Lack of clear knowledge on the deriving public benefits for your community / for the society	1	2	3	4	5	6	7	8	9
Lack of providers or of services of technical assistance	1	2	3	4	5	6	7	8	9
Market difficulties (lack of market knowledge; competition with leading enterprises)	1	2	3	4	5	6	7	8	9
Lack of linkages with universities/research centers	1	2	3	4	5	6	7	8	9
Research and development activities not addressing the needs of the enterprises	1	2	3	4	5	6	7	8	9
Difficulties to develop technical and financial partnerships	1	2	3	4	5	6	7	8	9
5. In your opinion, what are the major factors that favored / can favor the introduction of the bioenergy innovation?									
Growing energy needs	1	2	3	4	5	6	7	8	9
Investments / financial support	1	2	3	4	5	6	7	8	9
Research and development	1	2	3	4	5	6	7	8	9
Contribution to the quality of life / wellness of your community	1	2	3	4	5	6	7	8	9
Contribution to the environmental quality of your region	1	2	3	4	5	6	7	8	9
Reduction of green-house gases emissions	1	2	3	4	5	6	7	8	9
Obtaining public or social acknowledgement	1	2	3	4	5	6	7	8	9
Collaboration with providers and technical assistants	1	2	3	4	5	6	7	8	9
Collaboration with customers	1	2	3	4	5	6	7	8	9
Collaboration with other enterprises	1	2	3	4	5	6	7	8	9
Collaboration with Institutions	1	2	3	4	5	6	7	8	9
Collaboration with local research Centers and Universities	1	2	3	4	5	6	7	8	9
Collaboration with foreign research Centers and Universities	1	2	3	4	5	6	7	8	9
Expected economic returns	1	2	3	4	5	6	7	8	9
Social responsibility (benefit for the entire society)	1	2	3	4	5	6	7	8	9
6. In your opinion, what are the main factors stimulating the diffusion of innovation in the bioenergy field?									
Expected increase of energy demand	1	2	3	4	5	6	7	8	9
Behavior of entrepreneurs (availability to change; willingness to change; imitation)	1	2	3	4	5	6	7	8	9

Human resources (skills)	1	2	3	4	5	6	7	8	9
Contribution to the quality of life / wellness of the local communities	1	2	3	4	5	6	7	8	9
Contribution to the environmental quality of the region	1	2	3	4	5	6	7	8	9
Reduction of green-house gases emissions	1	2	3	4	5	6	7	8	9
Obtaining public or social acknowledgement	1	2	3	4	5	6	7	8	9
Social responsibility(benefit for the entire society)	1	2	3	4	5	6	7	8	9
Organizational strategy (clearly defined vision/strategy; established norms for innovation promotion)	1	2	3	4	5	6	7	8	9
Research and development	1	2	3	4	5	6	7	8	9
Social capital and partnerships (with local partners)	1	2	3	4	5	6	7	8	9
Social capital and partnerships (with foreign partners)	1	2	3	4	5	6	7	8	9
Policy measures (subsidies; fiscal deductions; norms and regulations)	1	2	3	4	5	6	7	8	9
Public investments (infrastructural investments)	1	2	3	4	5	6	7	8	9
Private business investments	1	2	3	4	5	6	7	8	9
Credit availability	1	2	3	4	5	6	7	8	9