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Sales Scale, Non-Pastoral Employment and Herders' Technology Adoption: Evidence from Pastoral China

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Abstract: The adoption of livestock husbandry technologies has been an important factor affecting the welfare of herders and the efficiency of grazing-based livestock production and grassland protection in China's pastoral areas. The small-scale herder is the main body of grassland-based grazing husbandry, and so technology adoption is particularly important, though it is currently scarce. To identify the factors influencing technology adoption behavior by Chinese herders, especially its effect on the scale of livestock sales and non-pastoral employment (NPE), we conducted a survey in the Gansu and Qinghai provinces of China with a sample of 296 herder households. The results show that the scale of livestock sale promotes the adoption of technology, while non-pastoral employment has a generally negative effect. In detail, the substitution effect of NPE is positive, but the wealth effect is negative. In addition, NPE and its wealth effect have moderating effects that can enhance the effect of the sales scale on the adoption of herders' technology. After distinguishing the technologies into profit-seeking technology and pro-environmental technology, we found that NPE and its substitution effect have a significant influence on pro-environmental technology, while the wealth effect has a significant impact on both profit-seeking and pro-environmental technology. Environmental awareness and altruism also have significant positive impacts on pro-environmental technology. These findings are relevant to policy implications dealing with technology adoption in pastoral areas.

Keywords: herder; technology adoption; livestock sales scale; non-pastoral employment; China

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1. Introduction

Technology adoption has been playing a key role during the process of economic development, and it is transforming traditional agriculture into modern agriculture on a global scale [1–3]. Previous studies have shown that the adoption of livestock husbandry technology can effectively improve economic and ecological benefits [4,5]. There exist many kinds of livestock husbandry technologies (e.g., remote monitoring systems, smart drinking water facilities, epidemic prevention facilities, shed cleaning and manure treatment equipment, etc.). While these technologies are mainly embraced by large-scale farms and/or households, small-scale herders cannot afford such technologies due to the high cost; therefore, the adoption of modern technology is scarce, especially in pastoral China, since the main body of grass-based livestock production is the household-based herder [6,7]. Meanwhile, grasslands are a major natural resource, and nearly 18 million herdsmen from the 268 pastoral and semi-pastoral banners (or counties) depend to a great extent on grasslands for grazing livestock for their livelihoods [4]. Although significant progress has been made across decades towards increasing production in pastoral China [8], productivity has not increased significantly, and grasslands are suffering from severe degradation [7,9]. Compared with rural areas of China and also with developed countries, the liquidity constraint and small scale lead to a relatively low level of technology adoption for grassland-based livestock husbandry [10,11]. Therefore, equipping small herders with modern technology is of great significance.

Previous studies on technology adoption behavior have been primarily focused on rural farmers and intensive or large-scale livestock farms instead of small herders. These existing studies can be categorized twofold. The first stream evaluates the production efficiency of such technology. Generally speaking, the technology can increase the production efficiency of livestock husbandry, but the efficiency varies according to the farming scales and regions [4,7]. In addition, the factors influencing the herders' propensity to adopt modern technologies have been identified, and previous studies have recognized that breeding years [4], herders' education level [7], an awareness or perception of technology [12], government promotion [10], herders' adaption to the climate [13], peer effect [12], etc., all have a significant influence.

Among these factors, farming scale and non-farm employment are two key influencing factors on farmers' technology adoption. In terms of scale, herders with different livestock sale scales are faced with different situations (e.g., risk preference, production objectives, costs and returns of technology adoption, and social status) and so they may make adjustments and reactions accordingly, which may result in different economic benefits [3,14,15]. With regard to non-farm employment, it is considered to be a guarantee for ensuring stable income and maximizing family utility, according to the theory of labor migration [16,17]. However, non-pastoral employment (henceforth, NPE) causes herders to face labor shortages and liquidity constraints in livestock production, which then influence their technology adoption behaviors in terms of the substitution effect and wealth effect. The substitution effect and wealth effect refer to the negative impact and positive impact, respectively, of NPE on livestock production [18]. For the substitution effect, the labor transition from rangeland to NPE leads to a shortage of labor in livestock husbandry production; thus, herders will choose non-labor-intensive technologies as a substitution for labor to maintain livestock production. However, the demand for the technology of the remaining labor decreases because of aging, the loss of household labor, and/or a diminished incentive for technology adoption [19]. For the wealth effect, non-pastoral income can alleviate herders' liquidity constraint, since it can be used to invest in livestock husbandry and to promote technology adoption [20,21]. Additionally, non-pastoral income can also be used for non-pastoral purposes, such as building a house, investing in children's education, and buying durable goods [22,23]. Moreover, the general higher pay of NPE compared to pastoral work leads to a higher opportunity cost of livestock husbandry production; therefore, the non-pastoral income will probably ease herders' dependence on grazing. This will, in turn, negatively affect the herders' preference and demand for technology [21,24,25]. In addition, since herders with different sales scales face different liquidity constraints and use their income from NPE in different ways, NPE will thus exert a moderating effect on the sales scale [18,24], and the effect of NPE may be strengthened or weakened. Studies related to the substitution effect and the wealth effect of NPE on herders' technology adoption behavior have not reached a consistent conclusion [19,22,23,26].

The objective of this study is to analyze the impact of livestock sales scale, NPE, and the moderating effect of NPE on the sales scale of herders' technology adoption behavior. The effect of NPE is distinguished into the substitution effect and the wealth effect. We focus on two categories of livestock husbandry technologies: one is the profit-seeking technology, which is represented by fattening and breed improvement; the other is pro-environmental or sustainable technology, represented by rotational grazing. The reasons why we pay attention to these three typical kinds of technologies are as follows. Firstly, herders traditionally sell lambs without fattening or buying forage, whereas herders currently have access to feeding markets to purchase forage, and the local government also encourages supplementary forage and intensive management. Therefore, some herders increase their forage and technical inputs, which can improve production efficiency and economic benefits [4,5,7]. Secondly, the sustainable development of the livestock industry relies to a great extent on the cultivation and the promotion of high-quality improved breeds. As a special input factor of livestock husbandry, improved breeds can increase productivity and the quality of the meat, and this is an important method for herders to increase their income [27,28]. Thirdly, rotational grazing is generally recognized as a pro-environmental technology, since it can not only improve livestock production, but also reduce the trampling losses of rangeland caused by livestock roaming for food; thus, the grasslands can be restored during rest periods [29,30]. Herders may react differently according to the different traits of the technologies [31–33].

This article attempts to complement previous studies by examining how sales scale instead of cultivation scale affects herders' technology adoption, since in pastoral China, especially in the Qinghai-Tibet plateau, herders do not cultivate livestock just for income. For example, the yak has always been regarded as an object of worship and is a symbol of family status under the influence of Tibetan Buddhism; thus, there is a large difference between the livestock farming scale and sales scale. The latter would be a more suitable proxy for seeking profit. Moreover, this study fills a gap in the literature by modeling the effects of NPE on herders' technology adoption from the perspective of the substitution effect and the wealth effect. It also contributes to the literature by distinguishing profit-seeking and pro-environmental technologies, and it tests the effect of environmental awareness and altruism on herders' technology adoption.

2. Data, Descriptive Analysis, and Models

2.1. Data

The data were collected in the Gansu and Qinghai provinces of China in October 2020. The grassland areas in the Gansu and Qinghai provinces are 14,300 and 39,500 hectares, respectively [34]. They are the traditional and typical pastoral areas of the Qinghai-Tibet Plateau, where the rangeland is mainly used for livestock grazing, and grassland-based livestock husbandry is the most important source of income and food for people living in this area, especially for the poor. These two provinces are an important production base for high-quality animal products. The total outputs of beef and mutton in 2020 were 525,000 and 325,000 tons, respectively [34]. The grasslands in the two provinces are an important ecological barrier for China and East Asia [35,36].

A multistage sampling procedure was adopted. Firstly, 10 counties were selected from the major grazing counties, according to the intensity of livestock production and the grassland area. In Gansu province, Maqu County and Tianzhu Tibetan Autonomous County were selected, as they conduct large-scale livestock production. Sunan Yugur Autonomous County and Subei Mongol Autonomous County were selected as examples of smaller production scale. For Qinghai province, Gangcha County, Zeku County, and Zhiduo County were randomly selected as they have a larger scale of livestock production. Chengduo County, Dari County, and Gande County were randomly selected because of their smaller livestock production scale. Secondly, 3 to 4 towns in each county were randomly sampled according to their scales of livestock production. Thirdly, 2 villages were randomly sampled in each town, and finally, 6 to 8 herder households were randomly selected from each sample village. Figure 1 shows the geographical locations of the 10 sampled counties.

A structured questionnaire was conducted to collect detailed information on the household and grassland characteristics, non-pastoral employment, livestock husbandry production, household income, householder's environmental awareness, and altruism. The questionnaire was developed through a literature review, followed by focus group interviews. We conducted face-to-face surveys with each household head for approximately 3 h. Since most herders in the sampled counties are minorities, the research group recruited volunteer interpreters who speak the local language (e.g., Tibetan, Yugur, and Mongol). To ensure the quality of the field survey, questionnaire training was conducted before the formal survey. A total of 334 questionnaires were collected, of which 296 were valid after excluding observations without livestock production, missing information on core variables, and suspected invalid data.

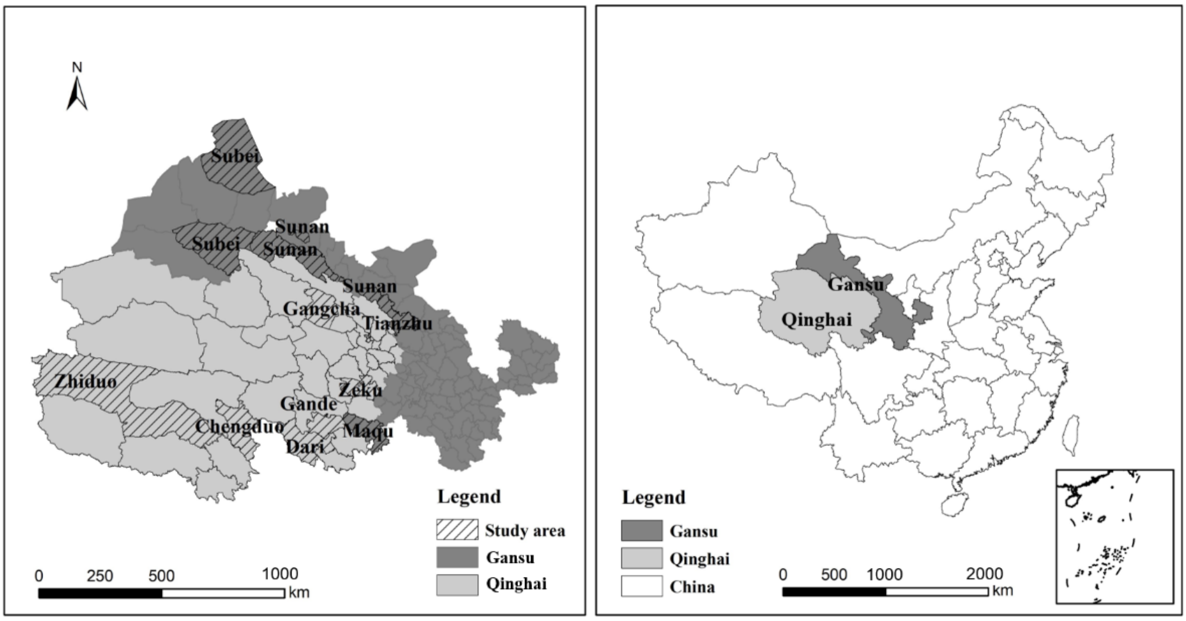

Figure 1. Locations of sampled counties.

2.2. Variable Definitions and Descriptive Analysis

The dependent variable was whether the herder was using technology. As mentioned above, the technologies included profit-seeking technologies represented by fattening and breed improvement, and pro-environmental technologies represented by rotational grazing. This indicator was recorded as 1 if any technology was adopted by the household, and 0 otherwise.

Core independent variables: (1) Livestock sales scale, or the number of livestock sold by herders in the current year, in sheep units; (2) non-pastoral employment (*NPE*), including local non-pastoral work and rural-to-urban migration, and measured by a binary variable that was 1 if any household member was employed in any non-pastoral work, and 0 otherwise. Furthermore, the ratio of the NPE time-of-household labor against the whole year was measured to identify the substitution effect of NPE, since it could more accurately characterize the degree of NPE, and could solve the estimation bias caused by the inconsistency of the time span of NPE [37,38]. The ratio of NPE income to the total household income was used to measure the wealth effect, representing the non-pastoral employability of herders. A larger ratio indicated a higher opportunity cost for livestock production [25].

Control variables: (1) Herder's environmental awareness and altruism tendencies were controlled as individual traits. Environmental awareness was measured by four easily understood questions: "Have you heard of the ecological environment?", "Have you heard of the grassland ecosystem?", "Have you heard of ecosystem services?", and "Will you actively watch the news about environmental protection?". A response of 1 indicated yes, and 0 indicated otherwise. The Cronbach's alpha of the four items was 0.78, confirming the validity of this scale. Altruistic tendency was measured by the inquiry "How much would you be willing to donate to a stranger who is suffering from a fatal disease (such as uremia, leukemia, cancer, etc.) through the 'Shuidi' crowdfunding platform (This platform is a widely used free fundraising platform in China, to raise medical expenses for patients with serious diseases who have financial difficulties.)"? The money for the donations came from the remuneration paid by our research group to the interviewees. (2) Social-demographic characteristics, such the ratio of male labor to the household's total labor force, education, the self-rated health conditions, level of Mandarin fluency, and technology training experience were controlled. The inquiry "How many people invited in your son/daughter' wedding" was also controlled, since it is an important proxy of the herder's social relationship or status [24,39]. Moreover, some other variables, such as whether the village had written informal regulations, the distance between the village office and the township office, and the distance between the village office and the county office were also controlled according to the previous literature [40–42]. The definitions of the variables and the descriptive statistics are shown in Table 1.

Table 1. Variable definitions and descriptive statistics.

Variables	Description	Mean	S.D.
	Dependent variables		
TA	Whether any of the two categories of technologies were adopted (No = 0, Yes = 1)	0.365	0.482
No_Tech	Number of technologies adopted {0, 1, 2, 3}	0.466	0.678
Profit_Tech	Whether profit-seeking technology was adopted (No = 0, Yes = 1)	0.233	0.424
Env_Tech	Whether pro-environmental technology was adopted (No = 0, Yes = 1)	0.226	0.419
	Exploratory variables		
Scale	Number of livestock sales in 2020 (sheep units) [a c]	73.753	109.180
NPE	Whether respondent participated in NPE (No = 0, Yes = 1)	0.486	0.500
Sub	Substitution effect: the proportion of the NPE time over the whole year (%)	0.117	0.170
Wealth	Wealth effect: the proportion of NPE income against household total income (%)	0.208	0.296
EA	Principal component analysis of the measurement scale of environmental awareness [b]	0	1
Alt	Altruism: donation ratio (%) [c]	0.207	0.260
Male	Proportion of male labor in total household labor (%) [d]	0.503	0.209
Age	Average age of household laborer (year)	37.968	9.557
Education	Average education level of household laborer (year)	5.312	3.676
Health	Average perceived health level of household laborer (very bad = 1, bad = 2, normal = 3, good = 4, very good = 5)	4.037	1.074
Mandarin	Average Chinese Mandarin fluency level of household laborer (cannot understand nor write = 1, only understand but cannot communicate nor write = 2, simple communication but cannot write = 3, proficient communication but cannot write = 4, proficient communication and writing = 5)	3.020	1.395
Training	Frequency of technology training attended by the household over the past three years (times)	0.682	1.919
No_Guests	Number of people invited to children's wedding (person) [c]	161.402	174.644
Informal_ins	Whether the village has written village regulations (No = 0, Yes = 1)	0.223	0.417

Table 1. *Cont.*

Variables	Description	Mean	S.D.
D_Town	Distance between the village office and the town office (km) [c]	19.908	32.663
D_County	Distance between the village office and the county/banner office (km) [c]	68.176	66.587

Notes: [a] Since herders usually cultivate multiple types of animals, sheep units were calculated to obtain aggregated livestock numbers based on previous studies [43,44], where a cow/cattle/yak was equivalent to 5 sheep units, a horse to 6 sheep units, and a camel to 7 sheep units. [b] The KMO test value was 0.718, and the approximate chi-squared value of the Bartlett sphere test was 398.92 (sig $\leq$ 0.001). We selected the first principal component with an eigenvalue greater than 1, and its variance contribution rate was 60.11%. [c] According to related research, *Scale*, *Alt*, *No_Guests*, *D_Town*, and *D_County* were divided into grades of 1–5 by quantile [24,41]. [d] Household labor is defined as members aged between 15 to 60.

Among the 296 households, the overall rate of technology adoption was 36.5% (Table 1). The average livestock sales scale was 73.75 sheep units. The proportion of households with NPE was 48.6%; among them, the NPE time accounted for 11.7% of the whole year, and the NPE income total was 20.8%. The average age of the household laborer was 38.0, the proportion of the male labor force in total labor was 50.3%, and the average education level of the labor force was 5.3 years.

2.3. Empirical Models

Whether a herder household adopts a technology or not is a binary selection variable; thus, a bivariate Probit model was used in this study. The basic form is as follows:

$$Y_i^* = \alpha + \beta Scale_i + \gamma NPE_i + \delta X_i + \varepsilon_i,\ Y_i^* = \begin{cases} 1 \ \ if \ Y_i^* > 0 \\ 0 \ \ if \ Y_i^* \leq 0 \end{cases} \tag{1}$$

where Y_i^* represents the latent outcome of household i, i.e., technology adoption; *Scale* is the livestock sales scale; *NPE* is non-pastoral employment; *X* represents the vector of the control variables; and ε is the random error term with standard normal distribution. β and γ are coefficients to be estimated. To further test the moderating effect of *NPE*, the interaction term $NPE \times Scale$ was added:

$$Y_i^* = \alpha + \beta Scale_i + \gamma NPE_i + \mu NPE_i \times Scale_i + \delta X_i + \varepsilon_i \tag{2}$$

It should be noted that in this nonlinear model, the regression coefficient is not a marginal effect; thus, the following conversion is required:

$$\frac{\partial P\ (y = 1/x)}{\partial X_i} = \frac{\partial P\ (y = 1/x)}{\partial\ (X'\beta)} \times \frac{\partial\ (X'\beta)}{\partial X_i} = \varnothing\ \left(X'\beta\right) \times \beta_i \tag{3}$$

3. Results and Discussion

3.1. Livestock Sales Scale, Non-Farm Employment, and Technology Adoption

Firstly, we analyzed the general impact of *Scale* and *NPE* on the technology adoption (Model 1). Secondly, *NPE* variables were replaced with *Sub* and *Wealth* to identify the substitution effect and wealth effect of *NPE* (Model 2). Thirdly, the interaction term $NPE \times Scale$ was included, based on Model 1, to test the moderating effect of *NPE* (Model 3). Finally, the moderating roles of the substitution effect and wealth effect were analyzed (Model 4), and two new interaction terms ($Sub \times Scale$ and $Wealth \times Scale$) were added to replace the interaction term of Model 3. The regression results are shown in Table 2.

Table 2. Estimated model of the impact of *Scale* and *NPE* on TA.

Variables	Model 1	Model 2	Model 3	Model 4
Scale	0.332 *** (4.33)	0.263 *** (−3.37)	0.196 ** (2.06)	0.182 ** (2.05)
NPE	−0.455 ** (−2.31)	—	−1.599 *** (−3.33)	—
Sub	—	1.140 * (1.85)	—	0.118 (0.06)
Wealth	—	−2.071 *** (−4.53)	—	−3.672 *** (−3.52)
NPE × *Scale*	—	—	0.334 *** (2.70)	
Sub × *Scale*	—	—	—	0.222 (0.47)
Wealth × *Scale*	—	—	—	0.570 * (1.71)
EA	0.061 (−0.64)	0.091 (−0.96)	0.058 (−0.57)	0.096 (−0.98)
Alt	0.103 * (−1.68)	0.088 (−1.43)	0.092 (−1.5)	0.082 (−1.31)
Male	−0.068 (−0.16)	−0.132 (−0.30)	0.02 (−0.05)	−0.106 (−0.24)
Age	−0.003 (−0.19)	−0.007 (−0.50)	0.001 (−0.07)	−0.007 (−0.47)
Education	−0.006 (−0.13)	−0.027 (−0.61)	−0.012 (−0.26)	−0.028 (−0.62)
Health	0.017 (−0.18)	−0.013 (−0.14)	0.009 (−0.1)	−0.012 (−0.12)
Mandarin	0.011 (−0.08)	0.078 (−0.51)	0.087 (−0.6)	0.097 (−0.62)
Training	0.095 ** (−2.24)	0.094 ** (−2.2)	0.090 ** (−2.08)	0.093 ** (−2.17)
No_guests	0.079 (−1.1)	0.068 (−0.94)	0.072 (−0.98)	0.065 (−0.85)
Informal_ins	0.443 * (−1.87)	0.535 ** (−2.16)	0.436 * (−1.8)	0.498 * (−1.96)
D_Town	−0.127 (−1.57)	−0.157 * (−1.88)	−0.126 (−1.56)	−0.160 * (−1.92)
D_County	−0.061 (−0.73)	0.091 (−0.96)	−0.084 (−1.00)	−0.09 (−1.06)
Constant	−0.563 (−0.48)	0.138 (−0.11)	−0.433 (−0.35)	0.376 (−0.29)
County	Controlled	Controlled	Controlled	Controlled
Observations	296	296	296	296
Prob > chi^2	0.000	0.000	0.000	0.000
Pseudo R^2	0.276	0.308	0.294	0.320

Note: The figures in parentheses are standard errors. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

3.1.1. Livestock Sales Scale and Technology Adoption

According to Models 1 to 4, *Scale* has a significant positive impact on technology adoption; that is to say, herders with large sales scale tend to adopt technology. This finding is consistent with Xu et al. (2022) and Pan et al. (2021) [15,24]. The possible reasons are as follows. Firstly, herders with a smaller livestock sales scale are probable risk avoiders in terms of technology adoption, since they always keep the 'survival rule' and 'safety first' principles in mind. In contrast, herders with larger sale scales are more market-oriented, and they often pursue the maximization of long-term income and sustainability of production [24,45]. Secondly, the cost of learning and information acquisition could lead larger herders to adopt new innovations earlier [46]; whereas herders with a small livestock sale scale cannot fully share the costs of learning to use the relevant technology, which hinders their acquisition of new knowledge and the adoption of new technologies [47]. For herders with a larger livestock sales scale, the unit cost of technology adoption (e.g., building fattening sheds and buying breeding sheep) is relatively low, but they can earn much more revenue through economies of scale [48,49]. Thirdly, in terms of technology availability, herders with larger sales scales are usually of a higher socio-economic status and have better access to public agricultural technology extension services. They are proactive in learning and adopting new technologies for the pursuit of profit [14,50,51]. Moreover, herders with larger sales scales tend to have a strong demonstration effect and they are faced with greater social pressure to take social responsibility, and so they may have stronger motivations to adopt new technologies during the livestock husbandry process [15,52].

3.1.2. Non-Pastoral Employment and Technology Adoption

NPE has a significantly negative impact (−0.455, $p < 0.05$) on technology adoption (Model 1). This finding is in line with Qian et al., in 2016, who found that non-farm employment forces rural family members who are left behind to turn to less labor-intensive production instead of more capital-intensive livestock cultivation [32]. According to Model 2, *Sub* has a significant positive impact (1.140, $p < 0.10$) on technology adoption. With the increasing proportion of NPE to household labor over the whole year, herders will increase their adoption of technology, resulting in a positive labor substitution effect of non-farm labor employment [19]. While *Wealth* has a significant negative impact (-2.071, $p < 0.01$) on technology adoption behavior, this result is consistent with Böhme (2015), who found that *Wealth* has a significantly positive effect on the accumulated agricultural assets, but not the same on livestock [52]. The possible reason for this is that livestock production and NPE are substitutes; NPE income can alleviate the liquidity constraints, but this causes livestock husbandry production to face higher opportunity costs, resulting in a negative wealth effect under the combined effect [24,25]. *NPE* has a negative impact on technology adoption after the superposition of the labor substitution effect and the wealth effect [21].

According to Model 3, *NPE* × *Scale* has a significantly positive effect (0.344, $p < 0.01$) on technology adoption. This means that the positive impact of *Scale* will be strengthened by the moderating effect of NPE. This finding is consistent with that of Pan et al. (2021) [24]. The possible reason for this is that herders with few livestock sales have a larger marginal income gap between livestock husbandry and NPE; they tend to shift more labor to NPE than to livestock husbandry, which inhibits their technology adoption. In addition, herders with many livestock sales are more inclined to use the remittance from NPE in livestock husbandry because the economies of scale; therefore, they have a higher preference for technology adoption.

According to Model 4, the estimated coefficients of the two interaction terms, i.e., *Sub* × *Scale* and *Wealth* × *Scale,* are both positive, but while *Wealth* × *Scale* has a significant effect (0.570, $p < 0.10$) on technology adoption, *Sub* × *Scale* does not (0.222, $p > 0.10$). This is because *Wealth* exerts a larger influence ($\mu = -2.017$) than *Sub* ($\mu = 1.140$) in Model 2 (Marginal effect results are not reported in the text. In Model 2, the marginal coefficient of labor substitution effect is 0.297, and the wealth effect is -0.537). The larger effect of *Wealth* plays a larger moderating role, while the smaller effect of *Sub* generates no significant moderating effect in Model 4.

3.1.3. Robustness Checks

We ran an array of robustness checks for the results in Table 3. The number of technologies adopted was considered a dependent variable (*No_Tech*) to replace the binary dependent variable in Models 1 to 4. The range of *No_Tech* is {0, 1, 2, 3}, and so an ordered Probit regression is used to test the robustness. In Models 5 to 8, *Scale* has a significantly positive influence on technology adoption. In Model 6, both *Sub* (1.118, $p < 0.05$) and *Wealth* (-2.037, $p < 0.01$) have similar effects to the baseline (Model 2). In Model 7 and Model 8, in terms of the moderating effect of *NPE* on *Scale*, *NPE* × *Scale* (0.288, $p < 0.05$), *Sub* × *Scale* (-0.298, $p > 0.01$), and *Wealth* × *Scale* (0.999, $p < 0.01$), all the measurements exert significant influences on technology adoption that are consistent with the benchmark models (Model 3 and Model 4). Only minor changes are observed for the control variables; thus, these results are not discussed. To summarize, the results are robust. Therefore, it can be concluded that *Scale* has a positive influence, but *NPE* has an inverse influence on herders' technology adoption. In terms of *NPE*, it can strengthen the positive effect of *Scale* on technology adoption. It has a relatively smaller positive substitution effect, but a larger negative wealth effect on technology adoption, which then leads to a different moderating effect of *Sub* × *Scale* and *Wealth* × *Scale* on technology adoption.

Table 3. Robustness test for the effects of *Scale* and *NPE* on *No_Tech*.

Variables	Model 5	Model 6	Model 7	Model 8
Scale	0.294 *** (3.61)	0.228 *** (2.80)	0.184 ** (2.05)	0.162 ** (1.99)
NPE	−0.311 * (−1.81)	—	−1.311 ** (−2.42)	—
Sub	—	1.188 ** (2.25)	—	2.066 (0.68)
Wealth	—	−2.037 *** (−4.67)	—	−5.1164 ** (−2.30)
NPE × *Scale*	—	—	0.288 ** (2.13)	—
Sub × *Scale*	—	—	—	−0.298 (−0.40)
Wealth × *Scale*	—	—	—	0.999 * (−1.69)
EA	0.130 (1.44)	0.167 (1.85)	0.129 (1.34)	0.182 *(1.92)
Alt	0.863 (−0.40)	0.066 (0.065)	0.075 (1.35)	0.061 (1.08)
Control variable	Controlled	Controlled	Controlled	Controlled
County	Controlled	Controlled	Controlled	Controlled
Observations	296	296	296	296
Prob > chi^2	0.000	0.000	0.000	0.000
Pseudo R^2	0.225	0.258	0.236	0.272

Note: The figures in parentheses are standard errors. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

3.2. Distinguishing Profit-Seeking Technology and Pro-Environmental Technology

In this session, we only emphasize the influences of *Scale*, along with *NPE* and its substitution effect and the wealth effect. The regression results are shown in Table 4. Models 9–10 and Models 11–12 show the results of profit-seeking technology (*Profit_Tech*) and pro-environmental technology (*Env_Tech*), respectively. In Models 9–12, *Scale* had a significant positive impact on the adoption of both *Profit_Tech* and *Env_Tech*, which was significant at the 1% level. *NPE* had no significant impact ($p > 0.1$) on *Profit_Tech*, but exerted a significantly negative effect (−0.295, $p < 0.10$) on *Env_Tech*. This finding was consistent with Feng et al. (2010), who found that non-farm employment has a significantly negative impact on the probabilities of investing in soil-improving inputs such as green manure and organic manure [31].

Table 4. Estimated model of the impact of *Scale* and *NPE* on *Profit_Tech* and *Env_Tech*.

Variables	*Profit_Tech*		*Env_Tech*	
	Model 9	Model 10	Model 11	Model 12
Scale	0.285 *** (3.89)	0.254 *** (3.36)	0.369 *** (4.93)	0.331 *** (4.38)
NPE	−0.268 (−1.42)	—	−0.295 * (−1.65)	—
Sub	—	0.618 (0.86)	—	1.763 *** (2.73)
Wealth	—	−1.162 ** (−2.49)	—	−2.440 *** (−4.54)
EA	0.086 (−0.89)	0.101 (−1.08)	0.213 ** (−2.12)	0.261 ** (−2.48)
Alt	0.023 (−0.37)	0.015 (−0.24)	0.138 ** (−2.05)	0.125 * (−1.82)
Control variable	Controlled	Controlled	Controlled	Controlled
Constant	−1.456 * (−1.92)	−1.125 (−1.43)	−2.991 *** (−3.77)	−2.549 *** (−3.16)
County	Controlled	Controlled	Controlled	Controlled
Observations	296	296	296	296
Prob > chi^2	0.000	0.000	0.000	0.000
Pseudo R^2	0.212	0.224	0.183	0.233

Note: The figures in parentheses are standard errors. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

In terms of *Profit_Tech* (Models 9–10), *Wealth* has a significant negative impact (−1.162, $p < 0.05$) but *Sub* is not statistically significant ($p > 0.01$). This is probably because profit-seeking technology (i.e., fattening or breed improvement) highly relies on the supply and service side. In addition to technology training, the promotion of fattening and breed improvement also requires a complete support system, such as the supply of frozen animal semen, sheep breeding, forage supply, sales markets, etc. In addition, fattening and breed improvement are cost-intensive since infrastructure construction such as sheds for fattening and breeding stock are expensive.

Regarding *Env_Tech* (Models 11–12), *Sub* has a significantly positive impact (1.763, $p < 0.01$). Since pro-environmental technology, i.e., rotational grazing, is non-labor-intensive, it is increasingly preferred by herders as NPE increases. However, *Wealth* has a significantly negative influence (-2.440, $p < 0.01$), with the probable reason being that the pro-environmental behavior cannot obtain economic benefits in the short term. The higher the NPE income, the greater the opportunity cost for the herders to adopt such pro-environmental technology [53].

3.3. Environmental Awareness, Altruism, and Technology Adoption

We also assessed the effect of environmental awareness and altruism on herders' technology adoption behavior. Environmental awareness, relating to people's perception regarding the environment and their responsibility for nature [54], exerts mixed effects on pro-environmental behavior and technology adoption [55,56]. Altruism (i.e., self-transcendent or prosocial behavior) is an attitude toward other people, and emphasizes the welfare of other human beings [57]. Relevant studies have shown that environmental awareness and altruism are important drivers in the decision-making process of humans for ethical behavior. Both also have significant impacts on farmers' pro-environmental technology adoption [56,58–60].

The regression results showed that environmental awareness and altruism had little significant effects on Models 1 to 8. However, after distinguishing *Profit_Tech* and *Env_Tech* (Model 9–12), both variables have significantly positive impacts on the adoption of pro-environmental technology. That is, the improvement of environmental awareness can prompt herders to adopt pro-environmental technologies, which can improve grassland ecology. The finding is in line with Wang et al. (2020), who found that environmental awareness can improve the enthusiasm of households towards participating in degradable agricultural mulch film compensation [56].

In addition, altruism promotes the adoption of pro-environmental technologies, which means that herders are more likely to engage in pro-environmental behaviors driven by altruism. This finding is in accordance with Bolderdijk et al. (2013) and Lades et al. (2021), who also claimed that altruism has been found to be an effective trigger for promoting pro-environmental behaviors [53,61]. The positive externality of rotational grazing technology cannot be realized in the short term; therefore, the adoption of such non-self-interested technology is more commonly triggered by altruism.

4. Conclusions and Implications

Livestock husbandry technology can promote the modernization of pastoral areas, which is of great importance as it can achieve profit-seeking and ecological benefits, especially for small-scale herders in northern China. Based on the survey data of 296 herders in 10 pastoral counties of Gansu and Qinghai provinces of China, this study analyses the influence of livestock sales scale and non-pastoral employment on herders' technology adoption behavior. The main results are as follows.

Firstly, the livestock sales scale promotes the adoption of technology. Large-scale households have advantages in resource endowments, and they have a stronger willingness and behavioral ability to adopt technology. The cost of technology adoption and the transaction cost are relatively lower, due to economies of scale. Therefore, these herders should be guided to conduct reasonable large-scale livestock production, especially to expand the sales scale based on local conditions.

Secondly, non-pastoral employment generally hinders technology adoption. The household labor shift to non-pastoral areas will encourage herders to adopt technology as a positive substitution effect of NPE; while the increase in NPE income has a negative wealth effect, since it increases the opportunity cost for livestock husbandry. In addition, the impact of sales scale on technology adoption can be strengthened by NPE and its wealth effect. Therefore, more attention should be paid to small-scale herders, such as the provision of technology training or preferential policies, and more channels of NPE should be expanded for large-scale herders.

Finally, environmental awareness and altruism have significantly positive effects on pro-environmental technology adoption. Since the average level of education in pastoral China is relatively low, more educational resources should be supplied to herders to make them more environmentally concerned to achieve the sustainable use of the grasslands.

This study provides a new research perspective on technology adoption in pastoral areas and livestock farming; however, we only focused on three technologies (fattening, breed improvement, and rotational grazing). Other technologies suitable for pastoral areas and especially small-scale herders should also be considered in the future. Future research could explore the economic and ecological benefits of the technology, as well as analyze the changing process of herders' technology adoption from a dynamic perspective.

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