Rural Agricultural Transformation: Is Family Labor Availability an Obstacle for Labor-saving Farm Technology Use among Smallholder Farmers?

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Abstract

Using the uniquely detailed data from a rural food insecure agrarian setting of Nepal, this study examined the relationships between family labor availability and use of modern labor-saving mechanical and bio-chemical technologies in agriculture among smallholder farmers. I use the labor demand framework to examine the relationships. Results from multi-nominal logistic regression revealed that the availability of family labor, both males and females, discouraged the use of such technologies in crop production net of household- and neighborhood-level factors. These findings provide important insights in leveraging problems of food insecurity through smallholder agricultural transformation in developing countries.

Keywords: labor, labor-saving, technology, rural, Nepal, South Asia

1. Introduction

UN World Food Programme (WFP) reports that 110 out of 210 countries—primarily poor countries with subsistence agriculture—are facing food security problems and this number is expected to continue growing (FAO et al., 2013). Despite the report of significant decline in the number of undernourished worldwide, still about 842 million people are estimated to have been in chronic hunger in the period 2011-2013. About 12 percent of the global population or one in eight persons are estimated to be not receiving enough food regularly to run active life. The vast majority of these undernourished people (827 million) live in developing countries. South Asia alone hosts 295 million (35 percent of the total) of them. Nepal is one of the most food insecure countries in the world with about 25 percent of the population below poverty with a ranking of 157 among 187 countries(UNDP, 2011; Joshi et al., 2012).Of the Nepal's 75 districts, 38 districts are characterized as food insecure (Ministry of Agriculture and Cooperatives, 2012). Subsistence nature of agriculture with low level of agricultural production and productivity associated with low labor productivity is considered one of the main reasons behind food insecurity (World Bank, 2013; FAO et al., 2013).

World agriculture has made a dramatic shift away from traditional farming systems toward increasingly mechanized, commercial farming systems during the second half of the 20th century (Mamdani, 1972; Self, 2008. This shift to commercial farming in peasant economies has many socio-economic, environmental and political implications. Some

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scholars argued negative consequences such as unequal distribution of economic benefits (Griffin, 1974; Jacoby, 1972), unemployment effects (Griffin, 1974; Jacoby, 1972), environmental effects (Biswas, 1994; Pimentel and Pimentel, 1991) and possible peasant revolutions (Scott, 1977; Paige, 1975; Skocpol, 1982). Contrarily, others advocate for the important role agriculture plays in reducing world hunger and food insecurity(World Bank, 2008; FAO et al., 2013; APP, 1995).Proponents of the technological revolution in agriculture—including agricultural modernization—have greatly emphasized the positive aspects of transitioning away from traditional, subsistence farming to mechanized, commercial farming. These positive aspects include increases in food production and productivity, declines in food prices, and overall socio-economic development (for example, Hazell and Ramaswamy, 1991; Mellor, 1976).

In developing countries, farm sizes are small (1.2 and 1.8 hectares in Asia and Sub-Saharan Africa, respectively) and family labor is commonly used to perform almost all types of agricultural operations such as land preparation, water management, fertilizer application, harvesting and post-harvest processing and storage (World Bank, 2008; 2013). It is reported that, in South Asia, the labor productivity is much lower in agriculture sector compared to other sectors. For instance, in Nepal, the productivity of agricultural labor is Nepali Rupees 700 (approximately US $ 7) per person compared to the labor productivity of NRs 2,817 (approximately US $ 28) per person in non-agriculture sector (ADB 7762-NEP, 2011). Thus, enhancing agricultural productivity (hence labor productivity) needs improvement in the use of modern farm technologies, through investment in areas such as of irrigation, farm roads, land improvement, agricultural mechanization, and the use of fertilizers and pesticides (Joshi et al., 2012).

Previous studies have primarily examined various economic factors such as prices, land size, and incomes contributing to technology use (Feder and O'Mara, 1981). Other researchers focused on micro-level explanations including household demographic and socio-economic characteristics on the use of farm technologies (Schutjer and Van der Veen, 1977; Feder and Umali, 1993; Rauniyar and Goode, 1992). This study, however, contributes to the existing literature by examining the relationships between labor availability and the use of modern labor-saving technologies among smallholder farmers in a rural agricultural setting. By examining this link, this study offers important insights in leveraging the transformation of smallholder agriculture in developing countries.

2. Background and Research Questions

Agriculture sector remains the major source of income and employment for the majority of Nepalese. It absorbs about 60 percent of the labor force for employment but has very low labor productivity (Upreti et al., 2008; ADB 7762-NEP, 2011). Farm sizes are very small, which declined to 0.7 hectares in 2010 from 1.1 hectares in 1995. In 2010, 52 percent of the holdings operated less than 0.5 hectares of land.

Agricultural productivity or yield (production per unit of land) in Nepal has remained stagnant or in some years declined during the last three decades. There is a wide gap in potential and actual agricultural productivity (ADB 7762-NEP, 2011). One of the main reasons for low agricultural yield is the low use of modern farm inputs and technologies (APP, 1995; ADB 7762-NEP, 2011; World Bank, 2008). In 2010, only 54 percent of the arable land was provided with irrigation. Most land is irrigable during rainy season only. Use of fertilizers islow, at 31 kg/hectare, one of the lowest among the neighboring countries in 1990 (APP, 1995). In fact, it is reported that the use of chemical fertilizers has actually declined to 19.6 kg/ha in 2000 (Leclerc and Hall, 2007). The level of mechanization is also low (APP, 1995; ADB 7762-NEP, 2011; Pariyar et al., 2001). Therefore, modernization of agriculture by providing farmers with new technologies is essential to reduce ever increasing food insecurity in Nepal (APP 1995). With this view in mind, the Nepalese government formulated and implemented a 20-year Agricultural Perspective Plan (APP) in 1995 with a strong focus on developing agriculture sector by encouraging farmers to use green revolution technologies such as mechanization, irrigation, fertilizers, and high-yielding varieties of seeds. More recently, Nepal's Government has planned to invest Rs 65.77 billion in the agriculture sector over a period of three years (2013-14 to 2015-16) to boost productivity and spur economic growth particularly through improving land and labor productivity (The Kathmandu Post, 2014).

Inadequate and untimely supply of quality inputs has been considered a major impediment behind low use of modern inputs in Nepal(APP, 1995; Parajuli, 2007; ADB 7762-NEP, 2011). Moreover, studies also reported macro-economic factors such as the demand and supply of fertilizers (ESCAP/FAO/UNIDO, 1997), fertilizer policy issues (Joshi, 1998; Tamrakar, 1998) and fertilizer trade liberalization issues (Basnyat, 1999). These studies primarily focused on issues of fertilizer acquisition, pricing mechanisms, and the distribution systems in the country. Studies of factors affecting modern inputs use at the micro-level are limited, however. In 2003, a study conducted by the Ministry of Agriculture and Cooperatives (2003) examined factors such as the price of fertilizer, prices of major agricultural outputs, wealth of household, size of cultivated land, and irrigation as some of the important determinants of fertilizer use. Regarding agricultural mechanization, very little research has examined the impact of mechanization on crop production, employment and income (Pudasaini, 1979) and the use of mechanization in the Nepalese agriculture (Salokhe and Ramalingham, 1998; Shrestha, 1998).

Interestingly, however, it is reported that 75 percent farmers were well aware of the modern inputs and their value even in early 1970s (Parajuli, 2007). Despite the fact, their use in Nepali agriculture up till now is still very low. It is further reported that farmers were hesitant to take risks due to the high cost of farm machinery, fuel, fertilizers, and pesticides. While aforementioned findings may be equally relevant, there is a paucity of studies that examine the role household-level labor availability may have on the use of various labor-saving modern inputs in crop production. Because the modern agricultural technologies such as mechanization, fertilizers, and pesticides are labor-saving in nature (Boserup, 1965), I argue that none- or low-use of these inputs may be associated with the availability of household labor in a context where family labor is the major source of farm labor. If cheap labor is already available to carry out farm activities, it is expected that the household might be reluctant to use labor-saving modern inputs. With this background, this study attempts to answer: *(i) to what extent does the availability of family labor influence the use of technologies in crop production, net of socioeconomic and neighborhood contextual factors?* Moreover, some of the agricultural operations in rural agrarian countries are gender specific (Acharya and Bennet, 1981; Agarwal, 1992; Sachs, 1996; Boserup, 1990; Kazinga and Wahha, 2013). Therefore, it is likely that the use of technology may replace gender-specific labor requirements in some specific sorts of operations and the presence of gender-specific labor in a household is expected to influence the use of labor-saving technology in farming. Therefore, this paper also attempts to answer *(ii) does the extent to which labor availability and technology use correlate differ by type of labor–males and females– net of socioeconomic and neighborhood contextual factors?*

3. The Setting

The Western Chitwan valley, situated in the southern plain of central Nepal, is the study setting. Before the 1950s, the valley was covered with dense forests and was infamous for malarial infestation. With U.S. assistance, however, the Nepalese government initiated a rehabilitation program in the valley during the 1950s by clearing the forest. Since then, the area has witnessed a rapid inflow of migrants attracted by the free distribution of land for agricultural purposes at the beginning of the settlement, and by the subsequent growth of modernamenities and services in recent decades. Currently, the valley is inhabitedmostly by in-migrants. Chitwan's central location and relatively well-developed transportation network have been the catalytic forces for transforming it into a hub for business and tourism. This has resulted in a rapid proliferation of government services, businesses, and wage labor opportunities in the district (Shivakoti et al., 1999).

Population in the valley is an admixture of Indo-Aryan and Tibeto-Mongoloid origins[i]. The household economy is primarily subsistence-based farming. A large majority of farmers practice crop-livestock integrated mixed farming production systems (Bhandari, 2004, 2013; Bhandari and Ghimire, 2013). Land is generally used to produce food. Animals are kept for milk, meat, eggs, draft power and manure. To a large extent, the labor needed for performing farm and other household activities comes from within the household. More recently, however, agriculture is experiencing modernization and the family mode of agricultural production has been rapidly changing throughout Nepal (Ministry of Agriculture and Cooperatives, 2003; Pariyar et al.,2001).

4. Theoretical Background

Everett M. Rogers (1960) offered the theory of diffusion of new ideas and subsequent adoption behaviors of farmers. According to Rogers, diffusion and adoption of new ideas takes place through five different stages: awareness, interest, evaluation, trial and final adoption of a new technology. He also pointed out other factors affecting the rate of adoption. For Rogers, if a new idea is affordable, simple, divisible (can be tried in a small amount), visible (outputs can be seen) and compatible to the farmer's condition, the rate of adoption is faster. Although many other factors have been studied to explain modern technology use in agriculture (Feder and O'Mara, 1981; Rauniyar and Goode, 1992; Schutjer and Van der Veen, 1977), Godoy et al. (1998) concluded that there is no single micro-level theory to explain technology use by farm households and therefore, pointed towards a need to develop a theory of adoption.

I utilize the household labor demand framework which is derived from the 'new home economics,' that originates from Gary S. Becker (1991) to assess the relationship between family labor availability and use of labor-saving technologies in agriculture. In many developing countries, a household is both a producer as well as a consumer and farm households are the primary units of decision making regarding farming practices (Becker, 1991; Ellis, 1993; Feder and Umali, 1993). The use of technologies —particularly those designed to perform labor intensive jobs—replace labor (Agarwal, 1983; Binswanger, 1978; Schutjer and Van der Veen, 1977; Boserup, 1965; Mamdani, 1972). Therefore, I expect that the availability of family labor may have important implications in the decision to use such labor-saving modern farm technologies.

Modern farm technologies are broadly grouped as–mechanical (tractors, pump sets and farm implements) and bio-chemical (chemical fertilizers and pesticides) technologies (Bartsch, 1977). Biologically, the effects of these two technology packages on agricultural production differ. While the use of mechanical technology increases labor productivity and agricultural production by improving the physical condition of soil and by timely completion of agronomic operations, the use of bio-chemical technologies increases production by directly affecting plant physiology. Therefore, the factors contributing to the use of these two technological packages may differ (Schutjer and Van der Veen, 1977).More importantly, some of the agricultural operations are gender-specific (Acharya and Bennet, 1981; Agarwal, 1992; Sachs, 1996; Boserup, 1990). Boserup (1990) indicated that in Africa, plowing of fields is primarily done by males and hoeing or weeding is done by females. This situation is not an exception to the Nepalese agriculture. Moreover, application of farmyard manure, weeding, and thinning out of disease and insect infested plants are primarily carried out by women. It is likely that use of technology may replace either male or female labor depending upon the nature of agricultural operations performed. Therefore, the presence of gender-specific labor in a household may affect the use of labor-saving technologies differently. Below, I discuss the mechanisms the household labor availability may influence the use of labor-saving modern mechanical and bio-chemical technologies in a poor rural agrarian settings.

4.1 Linkages between Labor Availability and the Use of Mechanical Technologies. In Nepal, land preparation for crop cultivation is generally performed by using human and animal labor. Men are responsible for plowing land. If there is a shortage of male labor in a household, alternatives are either to hire bullocks and a man or to hire a tractor (in *Terai*, the flat plain area). The use of tractors and power tillers for plowing land is gradually increasing. It is reported that the use of a tractor requires only one-fifth the labor that was needed to plow land compared to using a bullock (Agarwal, 1992; Bartsch, 1977). Since, a shift from human and bullock labor to a tractor replaces male labor, it is hypothesized that a household with more working-age males per unit of cultivated land is expected to be less likely to use a tractor. Farmers also use farm implements such as corn shellers, threshers, sprayers, and chaff cutters (Pariyar et al, 2001). Corn shellers are used for loosening grains from corn and sprayers are used for spraying chemicals such as pesticides and herbicides. A chaff cutter is used for cutting straw or fodder into small pieces. Although male labor is also used, females typically loosen corn grains. Similarly, a chaff cutter saves men’s time compared to women. The use of a sprayer generally increases male labor and saves female labor by reducing their time for weeding or removing diseased plants from the field. Altogether, these farm implements replace the need for human labor (Binswanger, 1978; Tunisia et al., 1990).

Use of rainfall and canal water is the common method used in irrigating crop fields in Asia. Nepal’s agriculture is no exception. In the Chitwan Valley, irrigation is provided by canal water during the monsoon season. However, in uplands a pump set is used. During dry seasons, canals are generally dry and pump set is the only source for regular supply of water. These days deep tube wells are also in practice. Evidence is limited whether the use of a pump set is a labor-saving or a labor-using technology. However, there are findings that traditional methods such as the use of the Persian wheel (an animal powered wheel with pots) and *charsa* (use of bullocks for lifting water from the well), commonly used methods in India, are labor-intensive as compared to pump set irrigation (Bartsch, 1977). Billings and Singh (Agarwal, 1983) in India reported that the substitution of a pump set for Persian wheels reduced human labor requirement to one-fourth of the previous level. Bartsch further reported that manual labor is greatly reduced when a pump set is used as compared to gravity flow. It is therefore hypothesized that: (a) *availability of working-age family members per unit of cultivated land reduces the likelihood of using labor-saving mechanical technologies; and (b)altogether, availability of working-age males per unit of cultivated land will have much stronger effect compared to females to reduce the likelihood of using labor-saving mechanical technologies.*

4.2 Linkages between Labor Availability and the Uses of Bio-chemical Technologies. Bio-chemical technologies refer to chemical fertilizers and pesticides (insecticides and herbicides). In Nepal, farmyard manure (FYM) or compost is the commonly used material to replenish soil nutrients. Recently, the use of chemical fertilizer is also increasing. In Swaziland, the use of chemical fertilizer is considered to be a labor-intensive technology, where it is frequently used as basal-dose and top-dressing (Rauniyar and Goode, 1992). Arnon (1987) also reported that the application of fertilizers may increase labor demand due to the need for more frequent and intensive weeding. In India, Bartsch (1977) indicated similar findings. In Nepal, anecdotal evidence suggests that the application of FYM demands a much higher level of human labor as compared to the use of chemical fertilizers. Labor is required to raise animals, prepare compost, carry out and apply the compost to the field. It requires a significant amount of labor as compared to buying, storing, and application of chemical fertilizer. FYM is primarily applied by women, although men and children also perform this task. Chemical fertilizer is applied primarily by men.

Similarly, manual weeding of unwanted plants is a common practice in Nepal and the task of weeding is performed by women. Although the application of pesticides is minimal in Nepal, their use tends to replace female labor. Rani and Malavia (1992) reported that one acre of land required 12.42 days for weeding by women in India. When herbicides were applied, the time required decreased to 0.42 days per acre. Therefore, it is hypothesized that (c) a*vailability of family labor in a household reduces the likelihood of using chemical fertilizers and pesticides; and (d) altogether, availability of working-age females per unit of cultivated land will have much stronger effect compared to males to reduce the likelihood of using chemical fertilizers and pesticides in agriculture.*

5. Data

This study used the Chitwan Valley Family Study (CVFS) household- and neighborhood-level data collected in 1996.The data was collected as part of the Population and Environment Study (PopEnv)[2]. The CVFS was primarily designed to examine the influence of rapidly changing social contexts on demographic processes including timing of marriage, childbearing and contraceptive use. The focus of the Population and Environment Study was to investigate the reciprocal relationships between marriage,

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[1]Both the Chitwan Valley Family Study and the Population and Environment Study were supported by the National Institute of Child Health and Human Development (NICHD). W.G. Axinn, Professor of Sociology, University of Michigan is the Principal Investigator.

childbearing, migration and other demographic variables, and environmental outcomes such as changes in land use, flora diversity, and water quality and vice versa. The data was collected at three different levels – neighborhood, household, individual. The data were collected from households in 151 neighborhoods scattered throughout the valley. A neighborhood was defined as a geographic cluster of five to fifteen households. These neighborhoods were chosen as an equal probability, systematic sample of neighborhoods in western Chitwan, and the characteristics of this sample closely resemble the characteristics of the entire Chitwan Valley population (Barber et al., 1997). Of particular interest, the access to non-family community services came from this neighborhood-level data. Next, the household-level information was collected through household census and household agriculture and consumption surveys in 1996. This study utilized data from 1,225 farm households within the neighborhoods. The census collected information on age, sex, marital status and individual relationships within the household. The agriculture and consumption survey collected information on household resources and assets, consumption and agricultural practices. Of particular interest, the survey collected information on the use of various farm technologies such as tractors, chemical fertilizers, pesticides, and farm implements in crop production, the size of cultivated land, land ownership, and livestock holdings. The data was collected through paper-pencil based face-to-face interviews with 99 percent response rate. Individual-level measures, age and education of the household head come from the individual-level data.

6. Measures

*Outcome meas*ures. There are two outcome measures–use of mechanical technologies and bio-chemical technologies. *Mechanical technology* included the use of a tractor, pump set and farm implements. Tractor use was measured by asking "Did your household use a tractor to plough the land for planting crop?" Similarly, the ownership of a pump set and farm implements such as a thresher, chaff cutter, sprayer, corn sheller, and other implements was measured as a dichotomy. The responses are coded "1" if a household used a technology and "0" otherwise. A three category summated index was created: (a) a household used none of them; (b) a household used any one of them; and (c) a household used any two or more of them. *Bio-chemical technology* included the use of chemical fertilizers and pesticides. Use of chemical fertilizers and pesticides was measured by asking whether a household used any chemical fertilizers and pesticides in crop production in the past three years. The responses were coded "1" if used and "0" otherwise. A three category summated index was created (a) a household used none of them; (b) a household used any one of them; and (c) a household used both of them.

Explanatory measures. Presence of working-age labor per unit of cultivated land is the major explanatory measure. Data on the number of working-age men and women 15-64 years of age living in a household at the time of survey was collected in 1996. As used by Rauniyar and Goode (1992) in their study of Swaziland, a household level measure of family labor availability, total, men, and women per hectare of cultivated land was created[ii]. Because majority of farmers have small land size, the availability of family labor per unit of land isan appropriate factor in the decision to use labor-saving technologies. Therefore, labor availability is adjusted for land size.

Controls. The models of relationships between family labor availability and labor-saving technology use also included a series of controls known to influence these relationships. The controls included: (i) age of the elderly person or the household head; (b) migration of family member(s) (coded as "1" if any member is away from home for work reason, and "0" otherwise); (iii) quality of cultivated land as (a) cultivated only *khet* land, (b) cultivated both *khet* and *bari* land, and (c) cultivate only *bari* land (percent of irrigated land was also used in the models of bio-chemical technology use); (iv) land ownerships; (v) land fragmentation (number of land parcels); (vi) livestock ownership; (vii) education of the household head or the elderly person; (viii) ownership of a radio and/or television; (ix) caste/ethnicity (grouped as Brahmin and Chhetri, Dalit, Newar, Hill *Janajati* and Terai *Janajati*); (x) access to community services (such as banks, cooperatives, markets, and transportation); (xi) presence of Small Farmers Development Program (SFDP)and (xii) proximity to the largest urban center of Narayangarh.

7. Analytic Strategy

First, descriptive statistics of all the measures used in the analysis are presented (Table 1). Second, bivariate relationships were examined (results not shown). Finally, as both the outcome measures, the use of mechanical and bio-chemical technologies have more than two nominal categories, multinomial logistic regression models were estimated to examine the relationships between farm technology use and family labor availability adjusting for all other factors (Hosmer and Lemeshow, 2000)[iii]. According to Hosmer and Lemeshow (2000), the multinomial logit equation is:

$$g_1(x) = \ln\left[\frac{\Pr(y=j)/x}{\Pr(y=J)/x}\right] = \alpha + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n$$

Where, $g_1(x)$ is the logit function, Pr(y=j) is the probability of the *i*th category of the dependent variable, α is the intercept, βs are the regression (slope) coefficients, and *x*s are the covariates. Models are estimated separately for mechanical and bio-chemical technologies and are presented as unstandardized β-coefficients and odds ratios (in parentheses).For simplicity, results are interpreted as odds ratios which are "the odds of having an event occurring versus not occurring, per unit change in an explanatory variable, other thing being equal" (Liao, 1994:16).Results for the association between labor availability and mechanical technology use and bio-chemical technology use (total: model 1a and 1b; male: model 2a and 2b; and female: model 3a and 3b), net of controls are provided in Tables 2 and 3, respectively. Within each group, the results in the first model (e.g. model 1a) is the relationships between labor availability and any one technology use vs. no use and the results in the second model (e.g. model 1b) is the relationship between labor availability and two or more technology use vs. no use[iv].

8. Results and Discussion

Seventy seven percent of the households reported that they used a tractor for plowing of crop fields, 14 percent reported they owned improved farm implements, and only four percent owned a pump set (Table 1). Of the total, 20 percent households used none of these three technologies, 66 percent households used any one of them and 14 percent of them used any two or more of them. Similarly, 83 percent households reported using chemical fertilizers and 23 percent reported using pesticides/ herbicides. Altogether, 16 percent households used none of these two chemicals, 83 percent of them used any one of them and 21percent used both of them.

Table 1: Descriptive Statistics of Measures, 1996 (N=1,225).

Measures	Descriptive statistics			
	Mean	Std. dev.	Minimum	Maximum
Technology use				
Package I: Bio-chemical technology use				
Fertilizer (used = 1)	0.83	0.38	0.00	1.00
Pesticides/ herbicides (used = 1)	0.23	0.42	0.00	1.00
Index				
Used both	0.21	0.41	0.00	1.00
Used any one	0.63	0.48	0.00	1.00
Package II: Mechanical technology use				
Tractor (used = 1)	0.77	0.42	0.00	1.00
Pumpset (own = 1)	0.04	0.19	0.00	1.00
Improved farm implements (own = 1)	0.14	0.35	0.00	1.00
Index				
Used any two or more	0.14	0.35	0.00	1.00
Used any one	0.66	0.48	0.00	1.00
Household labor availability				
Number of working age females/household	1.67	0.99	0.00	8.00
Number of working age males/household	1.72	0.96	0.00	10.00
Number of working age males and females/household	3.39	1.66	1.00	15.00
Household size	5.76	2.54	1.00	26.00
Household-level controls				
Age of head of the household (years)	41.78	12.52	15.00	80.00
Migration of individual from household (yes = 1)	0.25	0.43	0.00	1.00
Total cultivated land (*kattha)*	25.04	23.44	1.00	200.00
Land fragmentation (number of parcels)	2.12	1.23	1.00	6.00
Irrigated land (percent)	58.14	41.46	0.00	100.00
Type (quality) of cultivated land				
Khet only (yes = 1)	0.31	0.46	0.00	1.00
Bari only (yes = 1)	0.22	0.41	0.00	1.00
Khet and *Bari* both (yes = 1)	0.47	0.50	0.00	1.00
Land ownership: Full-owners (yes = 1)	0.72	0.45	0.00	1.00
Part-owners (yes = 1)	0.20	0.40	0.00	1.00
Sharecroppers (yes = 1)	0.08	0.27	0.00	1.00
Livestock ownership (yes = 1)	0.90	0.30	0.00	1.00
Education of head of the household (years)	4.18	4.53	0.00	16.00
Exposure to media (yes = 1)	0.54	0.50	0.00	1.00
Ethnicity: Bahun/Chhetri	0.49	0.50	0.00	1.00
Dalit	0.11	0.32	0.00	1.00
Hill Indigenous	0.16	0.37	0.00	1.00
Newar	0.06	0.24	0.00	1.00
Terai Indigenous	0.18	0.39	0.00	1.00
Neighborhood-level controls				
Number of services within a 10-minute walk	0.77	0.70	0.00	3.00
Presence of Small Farmer Group (yes = 1)	0.20	0.40	0.00	1.00
Proximity to urban center				
Strata 1 (close to urban center)	0.23	0.42	0.00	1.00
Strata 2 (between strata 1 and 3)	0.33	0.47	0.00	1.00
Strata 3 (farthest from the urban center)	0.44	0.50	0.00	1.00

1 hectare = 1.5 *bigha* = 30 *kattha*

A household, on average, consisted of about six individuals (mean = 5.76) (an average of 5.38 for Nepal and 5.79 for the central Terai in 2001). On average, a household had about 3.39 working-age individuals:1.67 men and 1.72 women (4.06 working age persons per hectare of cultivated land). A typical household head was about 42 years old. One in every four households had at least one member away from home for work reasons. A typical household had 25.04*kattha*(0.83 hectare; 1 hectare=30 *kattha*) of cultivated land. About 58 percent of the total cultivated land was irrigated and a large majority of the households reported that most of their land was irrigated during the monsoon season only. About 72 percent households were full owners, about one-fifth (20 percent) of them were part-owners and 8 percent of them were sharecroppers. The average number of parcels per household was 2.12. Ninety percent of the households reported that they kept animals (also a proxy of bullock ownership) such as cattle, buffalo, sheep, and goats. On average, a typical head of the household had slightly over four (4.18) years of schooling. Slightly over one-half (54 percent) of the households owned either a radio or a television or both. One-half of the households belonged to Brahmin/Chhetri, 18 percent belonged to the Terai *Janajati*, 16 percent belonged to the Hill *Janajati*, 11 percent were from *Dalit* and only 6 percent of them were Newar. Less than one service (mean = 0.77) was available within a 10-minute walk from the neighborhood. About 20 percent of the households belonged to a neighborhood where at least one member of the SFDP was present. About 23 percent of the households were in the area close to the urban center (strata 1), 44 percent of them were farthest from the urban center (strata 3) and the rest (33 percent) of them were in between these two areas. Below I describe the results of multivariate analysis.

8.1 Labor Availability and the Uses of Mechanical Technologies. The associations between family labor availability and the use of mechanical technologies (tractor, pumpset, and farm implements)are provided in Table 2. The results from the first set of models for total labor availability (model 1a and 1b) reveal that the increase in family labor availability per unit of cultivated land is negatively and statistically significantly associated with the use of mechanical technologies. For example, net of household- and community-level controls, a one person increases in total family labor per hectare of cultivated land reduced the odds of using any one item of mechanical technology by about 5 percent (odds ratio = 0.948; $p<.001$; model 1a) and two or more items of mechanical technologies by 19 percent (odds ratio = 0.812; $p<.001$, model 1b). Moreover, when the results are compared between users of any one mechanical technology vs. non- users (model 1a) and users of two or more mechanical technologies vs. none (model 1b), the magnitude of the associations was higher for two or more units. This finding is consistent with the hypothesis that increased family labor availability may be negatively associated with the likelihood of using labor-saving mechanical technologies in farming.

Table 2: Multinomial Logistic Regression Models of the Relationships between Household Labor Availability and Mechanical Technology Use (N=1,225).

Measures	Total models		Gender disaggregated models			
	Total labor		Male labor		Female labor	
	Used any one input vs. None (Model 1a)	Used both inputs vs. None (Model 1b)	Used any one input vs. None (Model 2a)	Used both inputs vs. None (Model 2b)	Used any one input vs. None (Model 3a)	Used both inputs vs. None (Model 3b)
Household labor availability						
Number of working-age labor/*hectare*	-0.054 (0.948)***	-0.209 (0.812)***	-0.081 (0.922)***	-0.301 (0.740)***	-0.105 (0.900)***	-0.357 (0.700)***
Number of working-age labor/*hectare* squared	-	-	-	-	-	- -
Household-level controls						
Age of head of the household (years)	-0.007 (0.993)	0.018 (1.019)+	-0.007 (0.993)	0.017 (1.017)	-0.007 (0.993)	0.020 (1.020)+
Migration of individual from household (yes=1)	0.461 (1.586)*	0.546 (1.727)+	0.442 (1.556)*	0.491 (1.635)+	0.448 (1.566)*	0.486 (1.625)+
Quality of land (Ref=*Bari* only)						
Khet only	0.176 (1.192)	1.299 (3.667)**	0.224 (1.251)	1.493 (4.450)***	0.170 (1.186)	1.361 (3.900)**
Khet and *Bari* only	-0.063 (0.939)	0.671 (1.956)	0.021 (1.021)	0.932 (2.538)*	-0.073 (0.930)	0.755 (2.128)+
Land ownership (Ref= Sharecroppers)						
Full owners (yes=1)	0.235 (1.264)	1.899 (6.676)*	0.176 (1.192)	1.828 (6.220)*	0.274 (1.315)	1.918 (6.809)*
Part-owners (yes=1)	0.124 (1.132)	1.097 (2.996)	0.108 (1.114)	1.097 (2.994)	0.158 (1.171)	1.117 (3.057)
Fragmentation of holding (no. of land parcels)	0.211 (1.234)*	0.488 (1.628)***	0.244 (1.276)*	0.554 (1.741)***	0.212 (1.236)*	0.500 (1.648)***
Livestock ownership (yes=1)	0.150 (1.162)	0.075 (1.078)	0.240 (1.272)	0.247 (1.281)	0.122 (1.130)	0.176 (1.192)
Education of head of the household (years)	0.044 (1.045)+	0.101 (1.106)***	0.048 (1.049)*	0.106 (1.112)***	0.042 (1.043)+	0.100 (1.105)**
Exposure to media (yes=1)	-0.078 (0.925)	0.731 (2.076)**	-0.078 (0.925)	0.751 (2.120)**	-0.073 (0.930)	0.748 (2.112)**
Ethnicity (Ref=Bahun/Chhetri)						
Dalit	-0.483 (0.617)+	-1.758 (0.172)**	-0.493 (0.611)*	-1.772 (0.170)**	-0.544 (0.580)*	-1.888 (0.151)**
Hill Indigenous	-0.012 (0.988)	-0.234 (0.791)	-0.006 (0.994)	-0.191 (0.826)	-0.031 (0.969)	-0.273 (0.761)
Newar	-0.050 (0.951)	0.033 (1.033)	-0.057 (0.945)	0.008 (1.008)	-0.071 (0.932)	0.058 (1.059)
Terai Indigenous	-0.384 (0.681)+	-0.703 (0.495)+	-0.430 (0.650)+	-0.798 (0.450)*	-0.405 (0.667)+	-0.763 (0.466)*
Neighborhood-level controls						
No. of services within a 10-minute walk	0.257 (1.293)*	0.073 (1.075)	0.253 (1.288)*	0.055 (1.056)	0.255 (1.291)*	0.064 (1.066)
Presence of Small Farmer Group (yes=1)	-0.739 (0.477)**	-1.361 (0.256)***	-0.733 (0.481)**	-1.343 (0.261)***	-0.743 (0.476)**	-1.380 (0.252)***
Proximity to urban center (Ref=strata 1)						
Strata 2 (between strata 1 and 3)	-0.381 (0.683)+	0.183 (1.201)	-0.384 (0.681)+	0.202 (1.224)	-0.361 (0.697)+	0.252 (1.286)
Strata 3 (farthest from the urban center)	0.172 (1.188)	1.622 (5.065)***	0.176 (1.192)	1.639 (5.149)***	0.199 (1.220)	1.734 (5.665)***
Intercept	1.162	-4.928***	0.886	-5.685***	1.155*	-5.359***
Chi-Square	341.146***		326.079***		337.689***	
-2 Log likelihood	1804.761		1819.828		1808.218	
Degrees of freedom	38		38		38	
McFadden Pseudo R-square	0.159		0.152		0.157	

t-statistic *** = p<.001; ** = p<.01; * = p<.05; + = <.10 1 hectare = 1.5 *bigha* = 30 *kattha* Figures in parentheses are odds ratios.

The relationships between gender disaggregated family labor availability and the use or non-use of mechanical technologies in farming were further examined. The associations between the presence of working-age males (models 2a and 2b; Table 2) and females (models 3a and 3b; Table 2) per hectare of cultivated land and the use of mechanical technologies reveal that, adjusting for all other factors, a one person increase in the availability of working-age male or female per hectare of cultivated land significantly reduced the odds of using either one or both items of mechanical technologies. For example, a one person increase in male laborer per hectare of cultivated land decreased the odds of using any one input (vs. using none) by 8 percent (odds ratio = 0.922; p<.001; model 2a) and both inputs (vs. using none) by 26 percent (odds ratio= 0.740; p<.001; model 2b). Similar were the results for female labor availability (models 3a and 3b). However interestingly, contrary to the expectation, the magnitudes of the associations for females were slightly stronger than those of males in both models.

8.2 Labor Availability and the Uses of Bio-chemical Technologies. Associations between family labor availability and bio-chemical technology use net of household- and neighborhood-level controls are provided in Table 3 (models 1a and 1b).Results revealed that increases in working-age family labor per hectare of cultivated land significantly decreased the likelihood of using bio-chemical inputs in crop production. For example, a one person increase in working-age family labor per hectare of cultivated land significantly decreased the odds of using any one item of bio-chemical input, either chemical fertilizer or pesticide, by about 3 percent (odds ratio = 0.975; p<.05, model 1a), net of all other factors. Similarly, a one person increase in family labor per hectare of cultivated land decreased the odds of using both items of bio-chemical inputs by over 5 percent (odds ratio = 0.949; p<.01), net of all other factors.

Table 3: Multinomial Logistic Regression Models of the Relationships between Household Labor Availability and Bio-chemical Technology Use (N=1,225).

Measures	Total models		Gender disaggregated models			
	Total labor		Male labor		Female labor	
	Used any one input vs. None (Model 1a)	Used both inputs vs. None (Model 1b)	Used any one input vs. None (Model 2a)	Used both inputs vs. None (Model 2b)	Used any one input vs. None (Model 3a)	Used both inputs vs. None (Model 3b)
Household labor availability						
Number of working-age labor/*hectare*	-0.026 (0.975)*	-0.052 (0.949)**	-0.046 (0.955)*	-0.084 (0.919)**	-0.052 (0.949)*	-0.108 (0.898)***
Household-level controls						
Age of head of the household (years)	0.004 (1.004)	0.013 (1.014)	0.004 (1.004)	0.013 (1.013)	0.004 (1.004)	0.013 (1.013)
Migration of individual from household (yes=1)	-0.086 (0.918)	-0.075 (0.928)	-0.083 (0.920)	-0.076 (0.926)	-0.090 (0.914)	-0.081 (0.922)
Irrigated land (percent)	0.002 (1.002)	0.004 (1.004)	0.002 (1.002)	0.004 (1.004)	0.002 (1.002)	0.004 (1.004)
Land ownership (Ref= Sharecroppers)						
Full owners (yes=1)	0.293 (1.340)	0.850 (2.340)*	0.268 (1.307)	0.814 (2.257)+	0.318 (1.374)	0.884 (2.421)*
Part-owners (yes=1)	-0.056 (0.945)	0.189 (1.208)	-0.066 (0.936)	0.182 (1.199)	-0.038 (0.963)	0.211 (1.234)
Fragmentation of holding (no. of land parcels)	0.449 (1.567)***	0.493 (1.638)***	0.466 (1.593)***	0.524 (1.688)***	0.446 (1.563)***	0.487 (1.627)***
Livestock ownership (yes=1)	0.102 (1.108)	-0.010 (0.990)	0.138 (1.148)	0.069 (1.072)	0.080 (1.083)	-0.040 (0.960)
Education of head of the household (years)	0.051 (1.052)+	0.106 (1.111)***	0.052 (1.054)+	0.108 (1.115)***	0.049 (1.050)+	0.103 (1.108)***
Ownership of radio and television (yes=1)	0.130 (1.139)	0.335 (1.399)	0.127 (1.135)	0.335 (1.397)	0.132 (1.141)	0.338 (1.402)
Ethnicity (Ref=Bahun/Chhetri)						
Dalit	-0.801 (0.449)**	-0.777 (0.460)*	-0.798 (0.450)**	-0.785 (0.456)*	-0.832 (0.435)**	-0.819 (0.441)*
Hill Indigenous	-0.200 (0.818)	-0.025 (0.975)	-0.202 (0.817)	-0.026 (0.975)	-0.211 (0.809)	-0.042 (0.959)
Newar	0.011 (1.011)	-0.582 (0.559)	0.011 (1.011)	-0.581 (0.559)	-0.005 (0.995)	-0.597 (0.550)
Terai Indigenous	-1.437 (0.238)***	-1.480 (0.228)***	-1.450 (0.235)***	-1.509 (0.221)***	-1.449 (0.235)***	-1.494 (0.225)***
Neighborhood-level controls						
No. of services within a 10-minute walk	-0.160 (0.852)	-0.316 (0.729)+	-0.158 (0.853)	-0.317 (0.729)+	-0.160 (0.852)	-0.315 (0.730)+
Presence of Small Farmer Group (yes=1)	-0.516 (0.597)+	-0.642 (0.526)+	-0.515 (0.597)	-0.639 (0.528)+	-0.520 (0.595)+	-0.648 (0.523)+
Proximity to urban center (Ref=strata 1)						
Strata 2 (between strata 1 and 3)	-0.860 (0.423)***	-0.443 (0.642)	-0.861 (0.423)***	-0.441 (0.643)	-0.853 (0.426)***	-0.431 (0.650)
Strata 3 (farthest from the urban center)	0.552 (1.737)+	0.739 (2.095)*	0.554 (1.740)+	0.746 (2.108)*	0.563 (1.756)+	0.758 (2.133)*
Intercept	0.928	-1.377+	0.850	-1.575*	0.950	-1.338+
Chi-Square	226.869***		224.617***		227.953***	
-2 Log likelihood	1989.992		1992.244		1988.908	
Degrees of freedom	36		36		36	
McFadden Pseudo R-square	0.102		0.101		0.103	

t-statistic *** = p<.001; ** = p<.01; * = p<.05; + = <.10 1 hectare = 1.5 *bigha* = 30 *kattha* Figures in parentheses are odds ratios.

Table 3 also presents the results of the associations between the presence of working-age male (models 2a and 2b) and female (3a and 3b) family members per hectare of cultivated land and the use of one or more units of bio-chemical inputs. Adjusting for all other factors, a one person increase in the availability of working-age members—either male or female—per hectare of cultivated land significantly reduced the odds of using any one or both items of bio-chemical inputs. For example, a one person increase in male laborer per hectare of cultivated land decreased the odds of using any one input by 5 percent (odds ratio = 0.955; $p<.05$; model 2a) and both inputs by 8 percent (odds ratio= 0.919; $p<.01$; model 2b). Similar were the results for female labor availability, with slightly stronger associations with female laborers than males. Interestingly, the magnitude of the associations between labor-saving technology use and female labor availability per unit of land is marginally but consistently greater across all models than the magnitude of the associations for male labor availability suggesting the significance of the availability of women labor force in the decision to use labor-saving technologies in agriculture.

8.3 Other Relationships. The findings also reveal the importance of other household- and neighborhood-level factors in the decision to use of modern technologies. The findings in the expected direction of these theoretically important measures suggest internal validity thus providing confidence in our results. As expected, education was positively associated with the use of modern technologies. Similarly, access to communication or a proxy measure for wealth or income - ownership of a radio and/or a television – positively influenced the use of mechanical technologies suggesting their important roles in technology use decisions. Migration of individuals was also positively associated with the use of mechanical technologies. Land ownership was significantly associated with the use of both technologies. Full land owners were more likely than sharecroppers to use them. This evidence is important in the context where land ownership has always been an issue for the development of Nepalese agriculture (NPC, 2003). In Nepal, dual land ownership prevails and emphasis is provided to abolish this system. The use of mechanical technologies also differed by quality of land. Those who cultivated *khet* land were more likely to use two or more items of mechanical technologies than those who cultivated only *bari* land. Although availability of irrigated land was positively associated with the use of bio-chemical inputs, the association was not statistically significant. The number of parcels cultivated by a farm household was found to increase the use of both technologies in crop production. This result is surprising, however. It could be due to the difficulty in transporting and applying farmyard manure in the distant fields as reported in Ethiopia (Gebeyehu, 1995). By caste/ethnicity, as expected, the findings revealed that the Terai *Janajati* and *Dalit* households were relatively disadvantaged in terms of using both bio-chemical and mechanical technologies compared to the Brahmin/Chhetri.

Despite the belief that no or low use of modern inputs is primarily due to their inadequate and untimely supply (APP, 1995; ANZDEC Limited, 2002; NPC, 2003), the results revealed, at least in the valley, that the associations between the use of farm technologies and the access to services (such as banks, cooperatives, and bus services), the presence of the SFD Program, and rural-urban location of farm households, however, were not clear. While the increased access to services increased the use of mechanical inputs, which is expected but decreased the likelihood of using chemical fertilizers and pesticides, which is in contrary to expectation. Rural-urban location of farm households also has a mixed effect on the use of various farm inputs. Households living in remote areas were more likely to use both of these farm inputs compared to those who are living in the vicinity of urban areas. It could be because of the fact that the households near the urban center may have other alternative income sources than farming and agriculture may not have received attention from the farmers.

9. Conclusion and Implications

Food insecurity is a global challenge. Most undernourished people live in developing countries and are mostly the subsistence based smallholder farmers. Although controversies abound about the roles of green revolution technologies worldwide, their roles can not be underestimated in increasing food production and therefore, in reducing world hunger and food insecurity. It is well recognized that many farmers in Asia and Africa are smallholders. Low use of production enhancing modern technologies by them and associated market access have been the major challenges in increasing agricultural production and thus, in alleviating the problem of food insecurity in those countries. Our results revealed that one of the reasons behind low use of modern inputs is due to the availability of family labor and their use among smallholder farmers. Previously, however, this empirical support was limited. This study contributes to the existing literature by examining these relationships between household labor availability and the use of modern labor-saving mechanical and bio-chemical technologies among smallholder farmers in a rural subsistence agricultural setting that is experiencing rapid commercialization more recently.

The findings provide evidence that the availability of working-age family members per unit of cultivated land discourage the use of both – mechanical and bio-chemical labor-saving technologies in agriculture. This could be the reasons behind low labor productivity in agriculture in Asia (World Bank, 2013; Ministry of Agriculture and Cooperatives, 2012). In addition, households having larger number of livestock may be more likely to reduce the use of chemical fertilizers because FYM can be a substitute of chemical fertilizer. Thus, the relationship between household labor availability and farm mechanization e.g. using tractor and other machines seems more salient as mechanization can be a substitute of labor availability mainly male. Moreover, from a gender perspective, the presence of both working-age men and women labor force per unit of land is equally important in the decision to use both of these technologies. Interestingly, the magnitude of the associations between labor-saving technology use and female labor availability per unit of land is marginally but consistently greater across all models than the magnitude of the associations for male labor availability. This is an important finding in the context where women's role in the economy is still neglected. Although the actual mechanism is not clear, this could be because women spend more time in household work including farming than men (FAO, 2000; Kumar and Hotchkiss, 1988; NESAC, 1998) and replace men's work wherever possible, for example, digging of crop fields, manual threshing and loosening of corn grains instead of using machines (corn sheller), etc. For example, FAO (2000) reported that women spend 10.8 hours per day in agriculture compared to 7.5 hours per day for men. This study provides important insights on the role of family labor availability on technology use which might be important for leveraging persistent food insecurity problem facing rural agrarian settings of developing countries.

This evidence is salient in the present context, where the country is experiencing unprecedented levels of out-migration, shortage of male labor, and increasing dependence on remittances. This shortage of labor due to out-migration may have been the main reasons behind increasing use of technologies by farmers. Additionally, both the large gender gap in out-migration and the low status of women in rural agricultural settings may also have important consequences in rural agriculture. Feminization of Nepali agriculture is another recent phenomenon. Due to unbalanced male out-migration, women are increasingly overburdened and are performing not only their traditional activities, but also the activities that were previously performed only by males (CBS, 2011; Maharjan et al., 2012; Gartaula et al., 2010). Given the gendered nature of farming operations, important consequences on women including changes in their roles, their time allocations, and health status can be expected, requiring further understanding.

Moreover, the existing agricultural development policies in Nepal basically focus on ensuring distribution of agricultural inputs while neglecting the role the availability of family labor that may play in agricultural modernization (ANZDEC Ltd., 2000). For example, thus far, the Ministry of Agriculture and Cooperatives has emphasized the distribution of inputs and their prices with the assumption that assured supply of inputs would encourage farmers to use them. This is reflected in the national policy documents. Obviously, the availability of inputs may be a constraint in the Hills and the high Hills and other remote districts of the country where the distribution of inputs is obstructed by rugged geographic terrain and transportation difficulties. However, such problems are not prominent in the Terai, particularly in the Chitwan Valley. Therefore, in a country where the family is the major source of labor and almost all activities including plowing, irrigating, weeding, and roughing of infested plants are performed by household labor, the provision of modern inputs may not be the primary solution to increasing their use.

The transition from subsistence, family-based farming to commercial farming is not without cost. Experience from the green revolution has already raised genuine concerns about its unintended negative consequences beyond increased production such as unequal distribution of economic benefits, unemployment, adverse health effects, and possible peasant revolutions (Griffin, 1974; Jacoby, 1972; Scott, 1977; Paige, 1975; Skocpol, 1982); and health and environmental effects (Pimentel and Pimentel, 1991). Therefore, it is crucial to gain a better understanding of the environmental and health effects caused by the use of chemical fertilizers and pesticides, along with the potential unemployment effects on both men and women.

Finally, I acknowledge various limitations of this study. First, despite the uniqueness and richness of the data used here, it is cross-sectional and was collected in one point in time in 1996. Therefore, these findings are rather associations than cause-effect relationships. Second, the data is collected from only one part of a district in the Terai plain. Therefore, findings will have to be used rather cautiously. For example, the findings related to mechanical technology use may not be appropriate for policy purposes for the Hill and Mountain districts of Nepal, where large machines (e.g. large tractors) cannot be used due to the topography. Third, the findings revealed a strong negative association between female labor pool in a household and the use of mechanical inputs. A further study is needed to explore mechanisms and changes in gender roles at this critical juncture when Nepali agriculture is rapidly being feminized.

Ethical Consideration

The data is publicly available through the Inter-University Consortium for Political and Social Research (ICPSR) at the University of Michigan at http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/4538?archive=ICPSR&q=nepal.

The author is certified with the human subjects protection "Program for Education and Evaluation in Responsible Research and Scholarship" at the University of Michigan. Thus, an independent ethical approval for the data used in this paper is not required.

Acknowledgement

This research was supported by a number of grants from the National Institute of Child Health and Human Development (NICHD) (Grant # R01-HD032912, Grant # R01-HD033551, and Grant # R01 HD033551-13) and a NICHD center grant to the Population Studies Center at the University of Michigan (R24 HD041028). I thank William G. Axinn (PI) and Dr. Dirgha Ghimire for providing access to the data. I also thank Drs. Shannon Stokes and Leif Jensen, my mentors at the Pennsylvania State University for their guidance and supervision. In addition, the research staff at the Institute for Social and Environmental Research-Nepal for their contributions to the research reported here and Cathy Sun for assisting with data management. Last but not least, I owe a special debt of gratitude to the respondents who continuously welcome to their homes and share their invaluable experiences, opinions, thoughts and have devoted countless hours responding to our survey questionnaires. All errors and omissions remain the responsibility of the author.

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Notes

[i]In general, the local indigenous (Terai Janjati) ethnic groups such as Tharu, Darai, Kumal and Chepang people follow traditional agricultural practices compared to Bahun/Chhetri, Dalit, Hill Janjati and Newar. The local ethnic communities raise animals in large numbers compared to other communities (Karan and Ishii, 1996).

[ii]Squared-term of labor availability is used to examine if any curvilinear effect of labor availability on modern inputs use exists. However, results are not shown.

[iii]First, as the technology use is measured in ordinal categories, I used the ordinal logistic regression. The test of parallel lines turned out to be statistically significant in all the models for both technological packages. This provided sufficient justification to reject the assumption of parallel lines. These results implied that at least one of the explanatory variables may have a differential effect across the outcome levels (O'Connel, 2006). Therefore, I used the multinomial regression as the analysis technique (Norusis, 2004).

[iv]Only models without squared terms of labor availability are presented.