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Impact of contract farming on yield, costs and profitability in low-value crop: evidence from a low-income country

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Lentils, a low-value and highly nutritious crop, are Nepal's largest pulse cash crop. However, the majority of the nation's smallholders produce lentils on very small plots of land. The large gap in lentil yields between Nepal and other lentil-producing countries underscores the importance of improving yields and income of smallholders. When it comes to the financial viability of small farms, particularly in developing countries, and globalisation, contract farming (CF) may prove useful in achieving efficiency and profitability in smallholder lentil farms in Nepal. This study employs the propensity score matching approach to examine the effects of the adoption of CF on yields, profitability and costs of smallholder lentil farms in Nepal. Findings from this study reveal that contrary to popular belief, CF adoption by lentil producers in Nepal has a positive and significant effect on per-hectare revenues, profits and yield and a negative impact on variable and transportation costs. The study finds that only very smallholder lentil farms (0.01–0.05 ha) benefit from CF.

Key words: contract farming, Lentil, low-value crop, Nepal, propensity score matching, treatment effect.

1. Introduction

Lentils were among the earliest domesticated plants, having been domesticated about 10,000 years ago in the Near East (Cubero *et al.* 2009). The bulk of lentil exports is concentrated among a few countries – Canada, the United States, Turkey and Australia – and major importers of lentils include India, Sri Lanka, the United Arab Emirates (UAE), Bangladesh, Egypt, Pakistan, Algeria and Iran. One nation that has not received much attention in the case of lentil production and exports is Nepal. Lentils play a major role in the livelihood, food security and nutritional security of Nepalese farmers and households. Although lentils are a low-value crop, they are a necessary protein and carbohydrate food, rich in essential dietary components and trace elements. It is the cheapest source of protein for poor and middle-class families in Nepal, and lentil '*dhal*' requires less cooking time than other pulses and thus economises

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Table 1 Trends in area, production and yield of lentil in Nepal, 1985–2013

Year (TE)	Area ('000 ha)	Production ('000 metric tonnes)	Yield (kg/ha)
1981	98.0	48.7	497
1991	120.6	74.5	618
2001	178.0	137.6	773
2013	207.2	214.0	1,033

Source: Authors' calculations based on FAOSTAT (2015).

Table 2 Share of lentil in gross cropped area (GCA), agricultural value of production (VOP) and total agricultural exports (TAE), Nepal, 1985–2013

Year (TE)	% share in GCA	% share in agricultural VOP	% share TAE (in value terms)
1981	3.40	2.38	0.00
1991	2.97	2.25	11.46
2001	3.95	3.07	10.83
2013	4.16	2.94	12.96

Source: Authors' calculations based on FAOSTAT (2015) and WITS database (2015).

fuel consumption. Finally, the inclusion of legumes such as lentils in the crop rotation increases soil nitrogen (N) fractions when residues are incorporated in the ground (Sainju *et al.* 2007).

Legumes such as lentils provide nutritional benefits through amino acid complementation of proteins when consumed with cereal grains, and they contribute environmental benefits through nitrogen fixation¹, even as per capita global production of pulses is declining (Vandenberg 2009). Lentils are effective as a rotation crop for sorghum/maize (Campbell *et al.* 1992). Lentils in Nepal usually are grown in rotation with rice, either as relay crop (zero-tilled) or immediately after the rice has been harvested and the soil cultivated (postrice system), or as a mixed crop with wheat, barley, mustard and linseed (Shrestha *et al.* 2005). In Nepal, the area, production and yield of lentils increased annually by 2.5, 4.7 and 2.1 per cent, respectively, during the 1981 to 2013 period (Table 1). However, Table 2 shows that lentils' contribution to the value of production increased marginally, from 2.4 per cent in the triennium ending (TE) 1981 to 2.9 per cent in TE 2013.

According to the U.S. Agency for International Development (2011), lentils from Nepal receive US \$1,364 per metric tonne, which is high compared to prices for lentils from other countries. Lentils are Nepal's largest export, yet there are significant constraints in productivity. Yields are low, at times the quality is poor, and processors operate at only 35 per cent of capacity. Lentil farmers fail to reach their potential for several reasons, including inefficient utilisation of land, use of traditional farming practices and a lack of market access. The large gap in lentil yields between Nepal and other lentil-producing

¹ Soil and crop management practices may alter the quantity, quality and placement of plant residues that influence soil carbon and nitrogen fractions (Thavarajah *et al.* 2011).

countries and the consumption needs of Nepalese people underscores an important opportunity for Nepal to improve yields and exports of lentils. Profit margins for lentil producers are highly variable compared to the margins for producers of other cereals and vegetables. Despite low yields and variable margins, farmers can potentially improve their livelihoods (incomes) and household food security. Farmers can increase their productivity and reduce production costs per unit of area by optimising production inputs, using improved machinery, and expanding marketing channels. Furthermore, the Government of Nepal in its Three-Year Plan (MoAC, 2010; GoN, 2010) has emphasised increasing agricultural production and productivity, increasing vertical linkages, increasing food security, and transforming subsistence agriculture into commercial farming and making it competitive. For the latter, policymakers want to reduce the farming risk of smallholder farms by including cash crops such as lentils, high-value crops and agribusinesses. To this end, development of vertical linkages (Swinnen and Maertens 2007) can contribute to reducing poverty and increasing food security in developing countries, including Nepal (USAID, 2011; Diao *et al.* 2012).

Contracts with companies such as processors, private seed companies or cooperatives can reap significant dividends for smallholders (Hazell *et al.*, 2007). Under contract farming (CF), cooperatives and companies alike send extension agents or field men to monitor the production process and ensure that the produce is of required quality (Bellemare 2012). CF with companies and cooperatives helps farmers receive high returns by increasing product quality and targeting market niches. CF in general reduces the cost of contract arrangement and coordination (Glover and Kusterer 1990) and of transactions (Key and Runsten 1999; Key *et al.* 2000; Alene *et al.* 2008; Ouma *et al.* 2010). CF in general ensures the marketing of produce, and cooperatives in particular reduce the cost of the farming business² and provide farmers with more bargaining power (Coulter *et al.* (1999; Baumann 2000), which results in higher profits to the farmers.

A plethora of literature has investigated the effect of CF on high-value crops (see Oya 2012; Wang *et al.* 2014; Otsuka *et al.* 2016). However, to best of our knowledge, none has investigated the impact of CF in low-value crops such as lentils, which contribute significantly to human health and agricultural sustainability. A plausible reason could be, as argued by Swinnen *et al.* (2010), that CF in staple crops such as lentils is less obvious, which are characterised by a low-value and high storability. As a result, a possibility of contract breaches.

The objective of this study was to analyse the impact of CF in lentils on *outcome variables* such as profit, yield and production costs of smallholders in Nepal. We also investigate the impact of CF in lentils for smallholders in

² Contracting companies or cooperatives in developing countries such as Nepal and India do not charge interest on inputs that they provide to farmers. This could be seen as a relaxing of credit constraints.

various farm size categories. The current study contributes to the literature on CF's benefits by employing a nonexperimental evaluation strategy to examine CF's impact on smallholders' profits, efficiency (yield per hectare) and costs (fixed and variables costs) from a sample of smallholders. CF could be attractive to both producers and processors in a country such as Nepal with a growing economy and high remittance income. Information on the impact of CF adoption in lentils on the profit, yield and costs of smallholders is critical for understanding how policy interventions interact with smallholder income and food security.

2. Conceptual framework and estimation strategy

The theoretical framework is borrowed from the literature (Singh *et al.* 1986; Sadoulet and de Janvry 1995), and we employ a nonseparable farm household model with missing market.³ The information-constrained smallholder household decides to adopt CF because it will increase income given the production function and land, labour and other resource constraints (Amare *et al.* 2012). Thus, a smallholder household i will adopt CF if the utility received in the form of profits from CF (CF_i^*) is greater than the utility from not adopting CF. The net farm returns can be expressed as a function of contract choice, AD (=1 if adopted CF; 0 otherwise). Using the first-order conditions, we can conclude that the adoption choice of CF, prices of inputs and outputs, and farm and household attributes tend to influence net returns from the farm, demand for inputs and farm output levels. Therefore, net returns in lentil farming for smallholder farms in Nepal tend to be influenced by, among other factors, participation in CF.

2.1 Methodological approach

The above discussion shows that CF can help farm families increase profitability (net farm income or profits) and subsequently the economic well-being of smallholder farmers in developing countries such as Nepal. However, it is challenging simply to attribute the difference in profitability, yield or reductions in the costs of production between CF adopters and independent lentil producers. It would be easy to establish the gains from CF participation if we had experimental data where one can randomise the experimental design and where information on the counterfactual normally would be provided. In this study, however, we use cross-sectional data, and no information on the counterfactual is being provided. In such cases, Blundell and Costa Dias (2000) conclude that the direct effect of participation in CF is shown by estimating differences in outcomes (such as yield, profitability and costs of production) among smallholders in Nepal.

³ The technology adoption literature in economics had its origin with the seminal work by Griliches (1957), who explained differences in technology adoption based on profitability.

Another issue with our survey data is self-selection. This issue is critical because the decision to participate in CF may be associated with net benefits. Let us consider a reduced-form relationship between the choice of CF and outcome variables (OV). Specifically:

$$OV_i = \beta_0 + \beta_1 AD_i + \beta_2 \theta_i + \eta_i \quad (1)$$

where OV_i represents an outcome variable (profit, yield and costs in our case) for smallholder households i . As in the previous section, θ represents household attributes and η_i is error term, with $\eta_i \sim N(0, \sigma)$ self-selection bias arises if unobservable factors influence both the error terms of the CF choice equation, μ_i , and the outcome equation, η_i , resulting in a correlation between the two error terms. Moreover, estimation using ordinary least squares (OLS) would yield biased estimates. Greene (2012) reveals several estimation techniques that can resolve this issue. These include the Heckman two-step method and the instrumental variable (IV) approach. However, Mendola (2007) shows that both OLS and IV procedures impose linear functional form and finding instruments is very difficult. Given this problem, our study follows Dehejia and Wahba (2002) using statistical matching to resolve the selection bias. Specifically, the method involves comparing adopters and nonadopters who are similar in their observable attributes. The authors note that when outcome variables are independent of assignment to the treatment group, the matching method can yield an unbiased estimate of the treatment impact (Mendola 2007).

Quantitative impact evaluations can be broadly classified as *ex ante* evaluation and *ex post* evaluation. An *ex ante* evaluation is the prediction of a future outcome based on a current situation and a simulation of the assumption about how the economy works. Let us define T as a binary variable equal to 1 if the smallholder adopts CF, zero otherwise; $Y(1)$ and $Y(0)$ are outcomes of the adopters and nonadopters, respectively. However, the fundamental problem, as noted by Caliendo and Kopeinig (2008), is measuring the individual treatment effect (ITE), $ITE_i = Y_i(1) - Y_i(0)$, which is not possible because we observe only one of the two potential outcomes. To this end, in our initial specification, we follow Rosenbaum and Rubin's (1983) propensity score matching (PSM) and focus our analysis on the average treatment effect on treated (ATT) because, as Becker and Ichino (2002) note, ATT can be considered the main parameter. Hence, the ATT for the individual can be defined as the difference between the expected *outcome* variable (profits, yield and costs, in our case) with and without CF adoption, for individuals who have access to CF. Specifically:

$$\begin{aligned} ATE &= E[Y(1) - Y(0)|T = 1] \\ ATE &= E[Y(1)|T = 1] - E[Y(0)|T = 1] \end{aligned} \quad (2)$$

Estimation of Equation (1) is possible as long as we assume that once we control for a vector of observable variables X , then adoption of CF is random. Caliendo and Kopeinig (2008) describe that given X (variables that are not affected by the treatment) potential outcomes are independent of the treatment assignment. Specifically:

$$\begin{aligned} \text{ATE}(X) &= E[Y(1) - Y(0)|X] \\ \text{ATE} &= E[Y(1)|T = 1, X] - E[Y(0)|T = 1, X] \end{aligned} \quad (3)$$

However, as noted by Smith and Todd (2005), a limitation of Equation (3) is that we cannot control for unobservable heterogeneity⁴, which may influence both adoption of CF and outcome variables (profits, yield and costs, in this study). The empirical procedure is to first estimate a probability model to calculate each smallholder farm's probability to adopt CF, that is the propensity score, and then calculate the ATT as:

$$T_{\text{ATT}}^{\text{PSM}}(X) = E[Y(1)|T = 1, P(X)] - E[Y(0)|T = 1, P(X)] \quad (4)$$

Several techniques can be used to match adopters and nonadopters of similar propensity scores. Matching estimators are considered nonparametric types of estimators because we do not need to assume a specific functional form and do not need to impose any distributional assumptions (Cameron and Trivedi 2005; Wooldridge 2010). Kernel-based matching (KBM) is the most commonly used method.⁵ This study uses this matching estimators with replacement. Stratified matching and Mahalanobis matching are also methods utilised in the literature (See Heckman *et al.* 1998; Caliendo and Kopeinig 2008).

The KBM method, a nonparametric matching method, uses weighted averages of the outcomes of all individuals in the nonadopter group ($T = 0$) to construct the counterfactual outcome.⁶ KBM is a local averaging method that reuses and weights all the comparison group observations in the treatment sample. Heckman *et al.* (1998) note that KBM requires the density of matching variables be strictly bounded away from zero. Therefore, as pointed out by Heckman *et al.* (1998), KBM would require the overlapping support region. Additionally, to avoid bad matches, the common support condition is crucial when using KBM.

Finally, a balancing test is required for the matching estimation method to check whether differences in the covariates in the two groups have been

⁴ In cross-sectional data analysis, this assumption is less restrictive than the weak instrument assumption in the case of instrumental variable or Heckman procedure (Jalan and Ravallion 2003).

⁵ We also used the radius-based matching (RBM) method, and the results were similar to KBM estimates. In the interest of time and space, we present only results for the KBM method.

⁶ Heckman *et al.* (1998) note that 'Non-parametric matching methods can only be meaningfully applied over regions of overlapping support'.

eliminated. The balancing property using the algorithm suggested by Becker and Ichino (2002) splits a sample into equally spaced intervals of propensity scores (blocks) and then tests in each block 'whether average propensity score between treated and control units is different'. Tests continue until the average propensity scores of the treated and control units do not differ in each block. If the means of each characteristic between treatment and control for same propensity score do not differ, the balancing test is satisfied. We restricted the algorithm to test in the area of common support (the area belonging to the intersection of the propensity score of treated and control), as this condition enhances the quality of matches in ATT estimation (Becker and Ichino 2002).

Now to test the balancing property, Rosenbaum and Rubin (1985) suggest that one should look at the standardised difference (SD) between treatment and control samples. The authors indicate that a $SD > 20$ per cent should be considered 'large'. Additionally, the pseudo- R^2 should be lower after matching. Finally, hidden biases may arise if unobserved variables affect both treatment and outcome variable, thus undermining the implications of the matching process. So the researcher's goal is to determine the strength of unmeasured variables in the selection process. In this case, Rosenbaum (2002) suggests a bounding approach to address the problem of hidden bias in matching models. The goal of a bounding approach is to assess the strength of unmeasured factors that may influence the selection process to weaken the inferences of the matching process. Empirical analysis will be accomplished through the STATA statistical package. The matching process is preceded by the specification of the propensity scores for the treatment variable.

3. Data and descriptive statistics

The study is based on a primary survey of lentil-cultivating households in Nepal, using a structured questionnaire. Information was collected at the household level, including farmer attributes, cropping patterns, costs and returns of lentil farming, marketing channels and other socio-economic characteristics. The survey was conducted during February and March 2015 in the districts of Bardiya, Banke and Chitwan in the mid-western and central regions of Nepal. The survey included these regions because CF among lentil farmers is pervasive in these regions. Additionally, the above districts were chosen because of high concentrations of lentil farming and the presence of some firms and cooperatives that procure lentil for processing. The firms and cooperatives that establish vertical and horizontal coordination with farmers include Durali Cooperative, Hare Krishna Cooperative, Komal Cooperative, Janmukhi Cooperative and Sidharth Mills, all in the Bardiya district; Krishak Upkaar Cooperative and Banke Daal Factory in the Banke district; and Shri Ram Farmer Cooperative in the Chitwan district. Cooperatives and processing firms engage in written or verbal contracts with farmers.

We surveyed 602 lentil farmers, comprising 300 contract farmers and 302 noncontract farmers, chosen randomly from 27 wards under seven village development councils (VDCs) from the three sample districts.⁷ The share of sample size allocated to each sample district was in proportion to the number of contract farmers. Approximately equal numbers of independent farmers were randomly identified for the survey in the same or immediate wards under respective VDCs of each sampled district. Hence, the number of farmers identified for survey from Bardiya, Banke and Chitwan districts was 300, 201 and 101, respectively. Smallholders who participated in CF of lentils signed or verbally agreed to a contract. There is no group signing or verbal agreement of contracts. Finally, all contracts were production contracts.

Smallholders with contracts in lentils allocated 52 per cent of their land to lentils (contract crop). On the other hand, independent smallholders allocated 44 per cent of their land to lentil production. However, the share of land allocation to lentils varied with the years of experience in contracting. For example, smallholders who entered into contracts in 2001 allocated, on an average, about 27 per cent of their land to lentils; a greater share of the land was allocated to wheat, chickpea, red beans, potato, oilseeds, pea and other vegetables. However, smallholders who entered contracts in 2014 allocated about 93 per cent of their land to lentils. Findings here show that CF leads to specialisation in the contracted crop. Farmers were asked whether the contractor provided any input or output conditions with the contract. Data reveal that 74 smallholders had contracts with only output conditions, none had contracts with only input conditions, and 226 had contracts with both output and input conditions. Information on economic variables (production costs, profits, revenue) was collected only for the lentil enterprise for both contracting and independent producers.

Table 3 presents definitions and descriptive statistics for the variables used in the empirical analysis. The average age of all farm operators is about 44, with 25 years of farming experience. The majority of operators report farming as their primary occupation and an average family size of six members. About 78 per cent of farm operators are male. The largest share, 47 per cent, has a 10th-grade education, and only 11 per cent have a high school education. Just 46 per cent of the households report owning a phone. Regarding costs and returns on lentil farming, the average smallholder farm reports significant labour costs (14,837/hectare Nepalese Rupee⁸, *NRs.*), and variable costs⁹ are significantly lower than labour costs. Finally, the average lentil farmer reports a yield of 1,080 kg/ha and average net profits of about *NRs.*1,916. The variables used in the present study are based on previous

⁷ Based on discussions with district agriculture development officers (DADO) of the Government of Nepal and farmer cooperatives in the districts.

⁸ Exchange rate was USD \$1 = 107 Nepali rupee (*NRs.*) at the time of the survey.

⁹ Includes cost of seeds, seed treatment, fertilizer (urea, potash, DAP), micronutrients, manure, pesticides, interest rate on working capital and miscellaneous.

Table 3 Characteristics of contract and independent lentil producers, Nepal, 2014–2015

Variable	All farmers	Independent farmers	Contract farmers	<i>t</i> -test of difference (<i>t</i> -stat)
Land area (hectare)	0.81	0.64	0.99	−7.78***
Age, head of household (HH, in years)	43.51	42.84	44.20	−1.25
Farming experience, head HH (years)	24.57	25.00	24.13	0.71
Household size (number)	6.48	6.23	6.73	−1.75*
Farming occupation (%)	0.98	0.96	0.98	−1.82*
HH with migrated member (%)	0.34	0.37	0.32	0.99
Male head of household (%)	0.78	0.75	0.82	−1.94*
Phone ownership (%)	0.46	0.42	0.50	−1.96*
Caste, general (%)	0.23	0.24	0.22	0.44
Caste, lower (%)	0.37	0.39	0.36	0.78
HH, 5th-grade education (%)	0.17	0.18	0.17	0.07
HH, 8th-grade education (%)	0.22	0.20	0.25	−1.51
HH, 10th-grade education (%)	0.47	0.50	0.44	1.39
HH, 12th-grade education (%)	0.11	0.10	0.12	−0.09
Total labour cost (both family and hired labour) per hectare (NPR†)	14,837.07	15,530.49	14,139.02	3.67***
Total input per hectare (NPR)	6,220.52	6,010.54	6,431.90	−1.38
Total variable costs‡ per hectare (NPR)	7,708.46	7,034.03	8,387.38	−3.37***
Total fixed costs§ per hectare (NPR)	25,334.51	24,603.91	26,069.98	−1.17
Total transport cost per hectare (NPR)	1,254.18	1,272.79	1,235.45	0.40
Total revenue per hectare (NPR)	80,187.32	75,045.30	85,363.62	−5.07***
Total profit per hectare (NPR)	24,832.58	20,593.52	29,099.90	−3.87***
Yield (kg, per hectare)	1,079.59	1,022.29	1,137.28	−4.54***
Total cost¶ per quintal (NPR)	5,516.28	5,668.75	5,362.80	1.71*
Net profit per quintal (NPR)	1,916.11	1,688.20	2,145.54	−2.51**
Wealth owned††(NPR)	8,635.83	5,947.12	11,342.46	−10.58***
Land owned (<=0.51 ha.)	0.37	0.49	0.25	6.27***
Land owned (0.52-<=0.85 ha.)	0.30	0.32	0.28	1.09
Land owned (>0.85 ha.)	0.32	0.18	0.46	−7.72***
District_Banke	0.33	0.29	0.37	−2.04**
District_Bardiya	0.49	0.48	0.51	−0.89
District_Chitwan	0.17	0.23	0.11	3.82***
Number of observations	602	302	300	

Notes: *Significant at the 10% level; **significant at the 5%; ***significant at the 1% level. †Nepali rupee; exchange rate was 1USD=107 Nepali rupee (NRs.) at the time of the survey. ‡also known as operation costs, which includes seeds, seed treatment, fertiliser (urea, potash, DAP), micronutrients, manure, pesticides, interest rate on working capital and miscellaneous. §includes the rental value of land owned, rent of leased land, land revenue or tax. ¶Interest rate on working capital was included in the cost calculation. ††includes values of land, bullocks, tractors, harvester and thresher owned.

Source: IFPRI-Nepal survey

research on the determinants of adoption of CF (see Barrett *et al.* 2012; Wang *et al.* 2014).

4. Results and discussion

The impact of adoption of CF on outcome variables (such as total profits, total revenues, total costs, total operation costs, total input costs and yield per hectare) was estimated with KBM method. Table 4 reports the results of the probit specification of the PSM. We also tested the model with other

specifications (sensitivity analysis) with other covariates, including district effects, and found the estimates to be robust. Figure 1 shows the distribution of the propensity scores and the region of common support. Figure 1 also reveals the distribution of propensity scores between contract and independent farmers. It shows the significance of proper matching and imposes the common support condition to avoid bad matches. Considerable overlap of the propensity scores of contract and independent farmers suggests that the assumption of common support holds. Finally, Table 5 presents the average treatment effects (ATT) estimated by the KBM methods and presents the indicators of matching quality (critical-level hidden bias, Column 5, Table 5).

Results in Table 5 indicate that the adoption of CF in lentils exerts a positive and significant impact on farms' total profits, revenues, fixed costs and yields per hectare. Specifically, the causal effect of CF adoption on profits (NRs. 10,911) suggests that profits of CF smallholder lentil producers are higher than those of independent producers by about NRs. 10,911 per hectare, mainly driven by output prices.¹⁰ In our sample, we find that contract producers receive higher prices (about NRs 75/kg.) than independent producers (about NRs 71/Kg). Higher prices indicate that contract producers receive a premium on the market price (Huh and Lall 2013). Our finding is consistent with Michelson *et al.* (2012) who found that independent producers, compared to contracted producers, have higher output but receive lower prices. Our finding is also consistent with Kumar *et al.* (2016), who found that contracted lentil farmers in Nepal received 81 per cent higher profits than independent farmers, mainly driven by higher prices.¹¹ Other studies (ICARDA 2015; Bhandari *et al.* 2015) also have reported the share of profit in value of production ranged between 30 per cent and 60 per cent in Nepal as well as in bordering states in India (Bihar). Additionally, the causal effect of CF adoption on total revenues¹² (NRs. 7,913) suggests that total revenues of CF smallholder farms are higher than revenues of independent farms by about NRs. 7,913 per hectare; however, the range of the estimates was much tighter. Our findings are supported by those in the literature (Engindeniz 2007; Kalamkar 2012; Otsuka *et al.* 2016). Indeed, contrary to the assertion of Swinnen *et al.* (2010), findings from our study show that CF in low-value crops such as lentils can help increase revenues and profits of smallholders in Nepal.

¹⁰ Additionally, Huh and Lall (2013) theoretically show that farmers under contract are shielded from price uncertainty, but are exposed to greater risk of quantity or yield uncertainty. 'Because of this trade off, the contract price may need to reflect a premium on the market price for farmers to accept the contract' the authors note. In another study, Ye *et al.* (2017) show that contract farmers decrease production quantity (focus on quality) as farmers face higher yield uncertainty and subsequently increase the retail price in the market.

¹¹ Findings from Bellemare and Novak (2017) and Sokchea and Culas (2015) also lend indirect support to our findings, as farmers in their study received higher income, due to CF.

¹² As one reviewer noted, and for reader clarification, total revenue is the revenue received from selling crop to the contractor. There is no home consumption from the lentil crop under CF.

Table 4 Propensity score for contract farmers (probit estimates)

Variable	Coefficient	Standard error	Z
Operational land area (hectare)†	0.954	0.109	8.68***
Age of head of household (HH, in years)†	0.407	0.206	1.98**
Farming experience of HH (years)†	-0.189	0.071	-2.66***
Household size (number)†	-0.271	0.143	-1.90*
Farming occupation (%)	-0.121	0.352	-0.34
Households with a migrated member (%)	-0.296	0.134	-2.20**
Male head of household (%)	-0.011	0.147	-0.07
Phone ownership (%)	0.285	0.124	2.29**
Caste, other backward castes (%)	0.328	0.174	1.88*
Caste, tribes (%)	-0.225	0.176	-1.27
HH member, middle school education (%)	0.399	0.185	2.16**
HH member, high school education (%)	0.133	0.167	0.79
HH member, intermediate education (%)	0.345	0.244	1.41
Wealth owned†	0.458	0.072	6.42***
District (1 = Bardiya)	0.077	0.200	0.38
District (1 = Chitwan)	-0.392	0.221	-1.77*
Constant	-4.376	1.045	-4.19
Number of observations	602		
Sensitivity (%)	72.67		
Specificity (%)	71.19		
Correctly classified (%)	71.93		
LR $> \chi^2(16)$	146.60		
Pseudo- R^2	0.22		

Notes: *Significant at the 10% level; **significant at the 5%; ***significant at the 1% level. †logged variable.

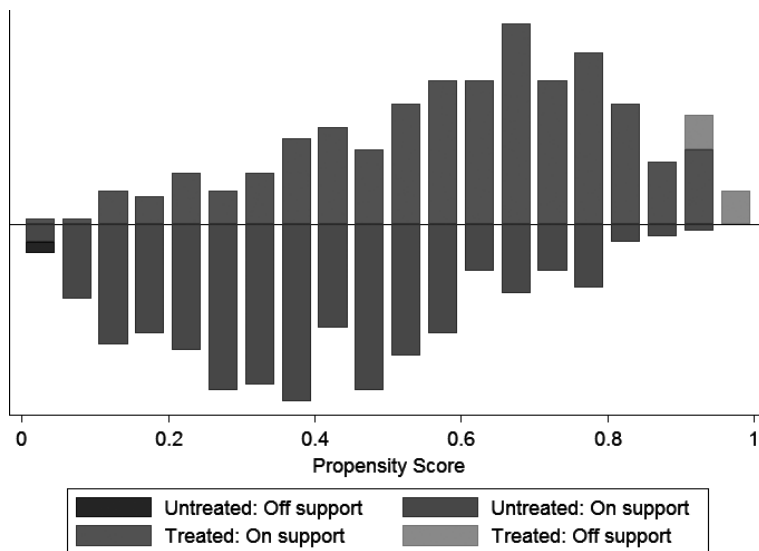


Figure 1 Propensity score distribution and common support for propensity score estimation. Note: 'Treated: on support' indicates the observations in the adoption group that have a suitable comparison. 'Treated: off support' indicates the observations in the adoption group that do not have a suitable comparison.

Table 5 Average treatment effects and results of sensitivity analysis

Matching algorithm	Outcome (per hectare)	ATT	t-stats	Critical-level hidden bias (Γ)	Number of treated	Number of Control
Kernel-based matching (KBM)	Total profits	10,911	3.72***	1.95–2.00	300	302
	Total revenues	8,541	3.35***	1.70–1.75	300	302
	Total fixed costs	–3,139	–1.71*	1.15–1.20	300	302
	Total costs	–2,193	–1.07	1.10–1.15	300	302
	Transport costs	–37	–0.29	1.05–1.10	300	302
	Yield (kg.)	88	2.73***	1.60–1.65	300	302

Notes: * and *** denotes statistical significance at the 10% and 1% level of significance.

Surprisingly, when it comes to fixed input and total costs, results in Table 5 show that farmers adopting CF have lower fixed cost (*NRs.* –3,139) than farmers who do not adopt CF. Additionally, the total cost estimate in Table 5 shows that adoption of CF in lentils exerts a negative and statistically significant impact on total costs per hectare. Findings suggest that CF can have a significant effect on the cost structure of smallholder lentil farmers in a small developing country such as Nepal, where farms are very small compared to farms in other countries in Asia and Africa. Our findings are consistent with Engindeniz (2007), but in contrast to Otsuka *et al.* (2016) and Kalamkar (2012). Finally, estimates in Table 5 show that CF adoption in lentils exerts a positive and statistically significant impact on yields. The yields of CF smallholder farms are higher than yields of independent farms by about *NRs.* 80 kg/ha. Our findings are consistent with Masakure and Henson (2005); Simmons *et al.* (2005); Engindeniz (2007); Tripathi *et al.* (2005); Dileep *et al.* (2002); and Kalamkar (2012).

Table 5, Column 5, also reports the sensitivity analysis for the presence of hidden bias. Recall that Rosenbaum bounds were calculated for outcomes between the treatment and the control group that are significantly different from zero (Rosenbaum and Rubin 1985). The lowest value of Γ is 1.05–1.10, and the largest critical value is 2.20–2.25. For example, for the impact of CF on yield, the sensitivity analysis suggests that at a level of $\Gamma = 1.55$, no hidden bias due to an unobserved confounder exists. In other words, if the odds of an individual being an adopter of CF are 1.55 times higher (or almost 55 per cent) because of the unobserved covariate, despite being identical on the matched (observed) covariate, there may be a change in the inference (Keele 2010). Following Mendola (2007), we can conclude that the inference on estimated effects will not be altered even in the presence of large amounts of unobserved heterogeneity. We find that our results compare favourably with findings from other studies (e.g. Faltermeier and Abdulai 2009) and are insensitive to hidden bias.

Recall that PSM is used to balance the distribution of relevant variables between CF adopters and nonadopters rather than to measure the precision of selection into a treatment group. To test this, we examine the reduction in the mean absolute standardised difference between the treatment and the control sample before and after matching (bottom half of Table 6). The

difference or the bias is calculated for each covariate. Table 6 reports these statistics. For example, in the original (unmatched) sample, almost 24 per cent of households had a migrated member in the treatment group, but this proportion was 30 per cent in the control group. The standardised differences could have impacted the treatment probability significantly. However, after matching (using KBM) the bias was reduced considerably, from -14.5 to 0.0 per cent. We performed a similar calculation for all the covariates. Table 6 (bottom half) also shows that a significant reduction in overall bias was achieved through matching. Recall from above discussions that the pseudo- R^2 from PSM should be as low as possible. Table 6 (bottom half, Columns 6 and 7) report the pseudo- R^2 from unmatched and matched propensity scores, respectively. The results reveal that joint significance of the regressors is always rejected after matching suggesting no systematic difference in the distribution of covariates between CF adopters and nonadopters. Therefore, through KBM, it was possible to generate a control group that resembles the treatment group to be used for the ATT estimation.

Finally, we report the impact (causal) of CF adoption on outcome variables (total revenue, profits, input costs¹³, transportation and total costs, yield) for different farm sizes¹⁴ (see Table 7). Although we find a positive and significant correlation between farm size (owned + rented hectares) and participation in CF, we find differential impact of CF on profits and costs, when taking into account various farm sizes. Based on our data, we have used three farm size categories (*small*, 0.01 – 0.51 ha; *medium*, 0.54 – 0.85 ha; and *large*, >0.85 ha). Results in Table 7 indicate that CF adoption in smallholder lentil farming exerts a positive and significant impact on farms' total profits, revenues, and on input, transportation and fixed costs per hectare. Unfortunately, CF does not have a significant impact on yields in any farm size category.

In the case of small farms (0.01 – 0.51 ha), the causal effect of CF adoption on profits (NRs. 9,427) suggests that profits of CF smallholder lentil farms are higher than those of independent farms by about NRs. 9,427 per hectare. Additionally, in the same size category, the causal effect of CF adoption on input and transportation costs suggests that input and transportation costs of CF smallholder lentil farms (0.01 – 0.51 ha) are lower than those of independent farms by about NRs. 660 and NRs. 375, respectively. A plausible explanation is that 65 per cent of small lentil farmers use CF with input conditions, in which the contractor provides input subsidies and transportation logistics, and such incentives tend to relax the credit constraints, provide inputs in a timely fashion and provide transportation of inputs to the farms and outputs to the contractor's warehouse. Our findings are in agreement with Miyata and Hu (2008), but in contrast to Singh (2002).

¹³ Includes costs associated with seeds, seed treatment, fertiliser (urea, potash, DAP), micronutrients, manure, pesticides and miscellaneous.

¹⁴ Size categories are based on owned hectares, only.

Table 7 Average treatment effects and sensitivity analysis results, by farm size category

Farming category (in hectares)	Matching algorithm	Outcome (in per hectare)	ATT	t-stat	Critical value of hidden bias (Γ)	Number of treated	Number of control
Small (0.01–0.51)	KBM	Total profits	9,427	2.23	1.40–1.45	76	149
		Total revenues	10,226	2.43	1.45–1.50	76	149
		Total fixed costs	767	0.50	1.05–1.10	76	149
		Total input costs	–660	–1.72	1.65–1.70	76	149
		Transport costs	–375	–2.01	2.50–2.55	76	149
		Yield (kg.)	83	1.55	1.05–1.10	76	149
		Total costs	799	0.40	1.05–1.10	76	149
Medium (>0.54–0.85)	KBM	Total profits	17,327	2.89	1.35–1.40	85	98
		Total revenue	2,407	0.54	1.20–1.25	85	98
		Total fixed costs	–16,079	–3.30	1.40–1.45	85	98
		Total input costs	760	0.91	1.50–1.55	85	98
		Transport costs	–15	–0.07	1.15–1.20	85	98
		Yield (kg.)	9	0.18	1.30–1.35	85	98
		Total costs	–14,920	–2.89	1.40–1.45	85	98
Large (>0.85)	KBM	Total profits	7,049	1.03	1.30–1.35	139	54
		Total revenue	10,979	1.65	1.70–1.75	139	54
		Total fixed costs	1,172	0.50	1.00–1.05	139	54
		Total input costs	419	0.55	1.45–1.50	139	54
		Transport costs	283	1.15	1.25–1.30	139	54
		Yield (kg.)	104	1.46	1.50–1.55	139	54
		Total costs	3,930	1.36	1.35–1.40	139	54

Note: Bold variables and values indicate statistical significance at 10% or higher level of significance.

In the case of medium and large farms, our estimates show that only a few outcome variables are significant. Recall that the comparison is being drawn between small farms, medium and large independent farms. For example, in the case of medium size farms (>0.54–0.85 ha), the causal effect of CF adoption is positive and significant on total profits (about NRs. 17,327) but negative on fixed costs (about NRs. –16,029) and total costs (about NRs. –14,920), compared to medium size independent farmers. Table 7 reveals that as the farm size increases to large (>0.85 ha), the causal effect of CF adoption on outcome variables (such as profits and costs) tends to diminish or become insignificant. The cost advantages (reductions) also vanish because large farms have more capacity (investments in machinery, land), and cost advantages small farms (see Mottaleb *et al.* 2015). This finding suggests that targeting very small-scale farmers (0.01–0.51 ha) with CF can have a significant impact on increasing revenues and profits and on reducing input and transportation costs.

5. Conclusions

Contrary to the assertions by Swinnen *et al.* (2010), our study found that CF in low-value crops, such as lentils, benefits smallholders in a small country such as Nepal. In particular, empirical findings from this study reveal that adoption of CF by smallholder lentil producers in Nepal had a positive and significant effect on per-hectare revenues, profits and yield. The estimates reveal that lentil yields are about 80 kg/ha higher for smallholder farmers who adopted CF than for farmers who did not adopt CF. Findings also show that profits are about NRs. 11,000/ha. higher for smallholder lentil producers who adopted CF than for producers who did not adopt CF. Finally, our study found that fixed costs are about NRs. 3,139/ha. lower for smallholder lentil producers who adopted CF than for producers who did not adopt CF.

CF's positive and significant impact on yield, profits and fixed costs underscores CF's importance in increasing the welfare of smallholder producer households. The estimates differentiated by land ownership indicate that most benefits of CF accumulate to very smallholder lentil producers (0.01–0.51 ha). These findings suggest that promoting CF is likely to benefit small lentil producers (0.01–0.51 ha.) – perhaps by relaxing liquidity constraints and transportation costs. Although lentil has been described as a low-value crop when it comes to CF, our results are contrary to that belief. CF has the potential to improve the food security of smallholders in Nepal.

An important policy implication of this finding is that targeting smallholder producers with new marketing and risk management strategies, such as CF, can improve farm productivity and profitability while reducing variable costs and reduce poverty among these small farm households. Increased lentil production potentially would improve nutritional and environmental aspects by increasing lentil consumption and encouraging environmentally sustainable cropping systems. Lentil is an ideal candidate crop to promote improved nutrition through whole food consumption on a global scale. Australia and Nepal could benefit from Australia trading market-ready lentil seeds to Nepalese retailers. Australian lentil companies can sell their heavily researched lentil seeds to Nepalese farmers for growth in Nepal, and many more jobs could be created in both countries. Future research can address CF's indirect effect on factors such as agricultural and nonagricultural wages, employment, and agricultural and food prices.

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