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The Effect of Harvesting Labor Constraints on the Production of Robusta Coffee Farmers in Chumphon Province, Thailand

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Abstract. Farm labor shortages are posing a challenge to the Thai agricultural sector, causing labor constraints. Farmers who grow Robusta coffee in Chumphon Province are highly dependent on seasonal migrant labor from northeast regions during the harvest season. However, recent changes in labor market conditions and the development of non-agricultural sectors across the country have increased the difficulty in finding seasonal farm labor, and this acute labor constraint may affect coffee production. This study examines the effects of this labor constraint on production outcomes and labor allocation. To identify constraints and the allocation of inputs, especially labor input, a quadratic production function is employed to estimate marginal productivity. An augmented inverse probability weighting estimator is then utilized as a double robust to estimate the average treatment effect. Our estimations found that the difference in the marginal productivity of labor inputs is not significant; however, the labor hiring constraint has a negative and statistically significant effect on coffee production. Thus, the exchange of labor information and providing information on coffee picking practice in the site are needed. Additionally, as farmer groups serve an important role in building stronger social ties and decreasing labor constraints, programs that implement technology and tools for supporting unskilled harvesting labor, labor information, and coffee farm practices should be implemented through farmer groups communities.

Key words: labor constraint, augmented inverse propensity weighted estimator, Robusta coffee, Thailand

1. Introduction

In the last 40 years, in Thailand, more than half of all farm labor has shifted from employment in the agricultural sector to other non-agricultural sectors in which production growth rates and wages are much higher[1]. Higher rates of education, as well as farming's relatively low- and insecure-income level, have turned younger generations away from farming and toward the industrial and service sectors[2].

Labor shortages in the farm sector are a national concern because labor is one of the factors that drive agricultural output, and therefore, agricultural growth and development in Thailand[2]. For example, the effect of labor shortages can be seen in Thailand's rice production. From 1989 to 1995, although the planted area increased and the planting methods improved, rice production still decreased due to labor shortages[1]. The continual decrease in farm labor has also affected the production quantity of rice, maize, and cassava, thereby affecting food security[3]. This problem could be a concern for rural livelihoods if the impact is significant for other cash crops. In Thailand, Robusta coffee was once a main source of income; in recent decades, farmers in Chumphon province have primarily devoted their land to planting this crop. Even though the

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production of Robusta coffee has decreased in production quantity and land area, it continues to contribute to the local economy. Coffee production is important on the household level, as it is responsible for farmers' incomes and indicates their farm management capacities, and on a national level in terms of competition in the global coffee market. The new goal of the five-year coffee plan (2017-2021) designed by the Thai government is to maintain coffee production and enhance coffee yield and productivity in this province. However, planted areas, production, and yield have decreased, and coffee has been replaced by other cash crops, such as rubber, palm oil, and fruit. As a production system, coffee cultivation is labor intensive, especially during the harvesting period[4,5]. Farm laborers on coffee plantations require a particular set of skills, and, in the light of the limited options for mechanization, dependence on physical labor is a necessary part of the plantation system[5]. However, this system has traditionally depended on seasonal migrant labor from the northeast region for harvesting work, and difficulty in finding this harvesting labor has become pervasive in recent years.

This study aims to examine the effects of this labor constraint on production outcomes and labor allocation for coffee production in Chumphon. However, to investigate the effect, the issue of concern is that labor constraints are not exogenously or randomly assigned to farmers, which implies that the endogeneity of labor constraints must be considered. Thus, this study introduces a doubly robust estimator, augmented inverse probability weighting (AIPW) estimation, on our original farmer survey in Chumphon province to test the hypothesis that the hiring labor constraint has a significant impact on coffee production. Moreover, how farmers cope with this harvesting labor constraint or labor allocation for coffee production is also in our interest. We hypothesize that farms under this constraint use family labor to compensate for the lack of available hired labor. To examine this behavior, we employed a quadratic production function to estimate the marginal productivities of family labor and hired labor.

This paper is organized as follows: Section 2 reviews labor constraint issues in Thai agriculture. Section 3 describes the labor requirements for Robusta coffee, specifically in the main production area of Chumphon province. Section 4 describes the methodologies in the study: applied production function and AIPW estimator. Section 5 presents the data collection and survey design. Section 6 demonstrates the estimation results, and Section 7 discusses the findings.

2. Labor constraint issues in Thai agriculture

Farm labor shortages pose a challenge to the Thai agricultural sector. In 2017, the total labor force in Thailand was 38.099 million people, or 57.56% of the total population, and 11.783 million people (30.9%) from this group represented the farm labor force[6]. However, from 1977 to 2017, the farm labor force in the country decreased by more than half, from 67.2% to 30.9%, which is an annual decrease rate of 0.33%[6]. Meanwhile, during the same period, the labor force employed in the non-farm sector rose from 31.7% to 67.4%[6] (Fig. 1).

This declining trend in the farm labor force (defined as those aged 15-64 years) was particularly sharp among those aged 15-24 due to a rise in educational enrollment, which caused many young workers to engage in other sectors as the country has become more industrialized[1,7]. In addition, the decline in the number of young people who want to work in farming has also led to agricultural labor scarcity[2]. Moreover, the average age of the heads of farm households reached 56.26 years by 2017. From 2005 to 2017, the percent of farm household heads over the age of

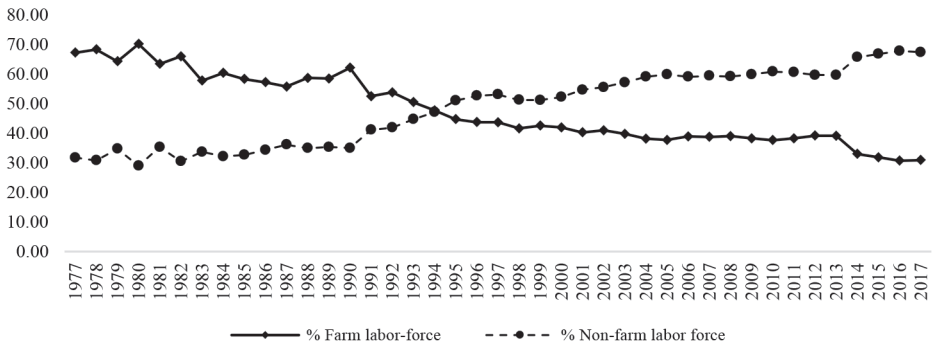

Fig. 1. Percentage changes in the labor force employment status in the period from 1977 to 2017
Source: Labor Force Survey in Thailand, National Statistical Office, Ministry of Information and Technology, updated and published by Bank of Thailand (BOT)

60 increased from 29.34%[8] to 39.29%[9].

This situation is common across the country; the number of agricultural laborers has shown a gradual decline in every region. From 1998 to 2014, the farm labor force decreased from 22.80 million to 17.78 million, decreasing by an annual rate of 1.18%[10]. This trend occurred across all regions; farm labor has decreased by 0.74% in the north, 1.58% in northeast, 1.35% in central, and 0.19% in the south[10].

Even though Thailand imports and uses immigrant labor from neighboring countries (89.3% of this labor comes from Myanmar), laborers prefer to work in agro-industries and the service sectors because the farm sector offers only seasonal jobs, which do not provide secure incomes[11]. Moreover, there are many regulations that limit the availability of alien laborers to work on farms, and farm work is not so different from the work available in their own countries and provides lower pay compared with non-farm jobs[11]. Moreover, there are long-term disadvantages—it would be impractical to rely on foreign or immigrant labor because of the advanced economic progress of neighboring countries, which often tempts immigrant laborers to go back to their homelands[11].

Many studies in Thailand clearly reveal that labor is one of the most important inputs in agricultural production. Perennial crops, such as longan, have also been affected by labor shortages, especially during the harvest season in the northern regions, including Chiang Mai and Lamphun provinces. The lack of harvest labor has affected production in term of both the quantity and quality of products. Thus, the demand for labor to harvest longan, especially migrant and foreign laborers from Myanmar, has greatly increased[12,13]. Moreover, labor shortages have also been found to significantly affect palm production in Krabi province, the main location for palm oil in Thailand[14], and chili production in Sakhon Nakhon province[15]. Labor is especially important for labor-intensive crops, such as perennial crops like rubber, because technology and machinery cannot help much with the production of these perennial crops[16].

Thus, labor shortages in the farm sector are a national concern because they have not only led to an increase in the cost of human labor, but have also affected the performance of timely farm operations, thereby affecting productivity levels and the growth of the sector[2]. Moreover, labor shortages are especially problematic for seasonal crops for which their insufficient technological labor substitution; Robusta coffee is one of these crops.

3. Labor requirements for Robusta coffee production in Chumphon province

Chumphon has produced Robusta coffee since the 1980s. The general characteristics of Robusta coffee are as follows: Robusta coffee is suitable for growing in the warm and humid climate of southern Thailand. It has a higher level of disease resistance, quicker fruit maturing, and higher bean productivity than other coffee types[17, 18]. Moreover, Robusta coffee produces a round bean that distributes a stronger taste and provides more caffeine compared to Arabica[18]. These characteristics are why coffee growers in southern Thailand prefer to grow Robusta coffee.

Before introducing the current labor situation in the region, the labor requirements for production should be confirmed. The types of operations and their labor needs are summarized in Table 1. This information is based on discussions with farmers in the study region. Some operations require hired labor when the family cannot fully satisfy the labor requirements. For example, fertilizers (chemical and manure) are applied around 1-3 times a year. Family labor is mostly used for applying fertilizer; however, if there is a of lack of family labor, local labor will usually be hired.

However, there is a scarcity of labor for certain operations requiring skill, especially harvesting/picking work. Moreover, in the Robusta coffee area in Chumphon province, there was no mechanical harvest applied by either small or larger farms to pick coffee beans. Traditionally coffee was harvested by hand by mostly the way of selective picking. Harvesting labor selective picking involves making numerous passes over the coffee trees, selecting only the ripe cherries, then returning to the tree several times over a few weeks to pick the remaining cherries as they ripen. For the final harvesting of the remaining coffee cherries, the coffee trees are harvested entirely in a one time “stripping” all the beans off the branches, unripe as well as ripe cherries. Labor constraints in this work is a significant factor affecting the quality and quantity of coffee because picking coffee berries is intensive work and most berries mature contemporaneously across villages. Labor constraints in this limited time period can result in both a loss of mature coffee berries as well as the incorrect harvesting of unmatured berries, resulting in reduced coffee production[17]. Coffee growers must use family labor plus seasonal labor to cope with their labor needs at this time. The picking process cannot be skipped; thus, labor constraints will affect the quantity and quality of coffee production.

The evidence from other coffee studies indicate that

Table 1. the main activities on coffee operations

Coffee operations	time per year	Labor use	Wage rate	In case of shortage/ coffee grower response by
Pruning coffee tree branch/ Shade trimming	1-4 times a year	Mostly skill family labor. and hiring from local	Per-day (300 baht/day)	No shortage but faced tight situation of labor available because it needs highly skilled labor/ skip the operation
Apply fertilizer	2-3 times a year	Family labor, and hiring from local	Per bag of fertilizer (40 baht/bag)	No shortage/ if sometime shortage of labor arise, using more family labor.
Weeding (Pesticide/ herbicide)	1-4 times a year	Family labor, and hiring from local	Per-day (300 baht/day)	No shortage/skip the operation
Harvesting	Once a year/ The harvesting time was from late October until early February	Use family, and hired labor mostly from northeast	Per kg. (average is 2.5 baht per kg) one labor can harvest 250 kg cherry per day	Labor shortage is an issue in this operation. Using family labor/local labor/ resort to higher payments
Drying coffee berries	Once a year after harvesting	Mostly use family labor	-	No shortage
Transporting to the market/buyers	Once a year after harvesting	Mostly use family labor	-	No shortage

Source: Authors' survey and the Handbook for the Management of Main Perennial Crops, Department of Agricultural Extension, Agricultural Statistics Yearbook, Office of Agricultural Economics.

farmers primarily hire laborers from the northeastern region[17, 19, 20]. This is consistent with the interviews conducted with farmers in our study region, who reported that 87% of farms hire extra labor from this region for coffee harvesting, or they contract with northeastern laborers. This is because most coffee farmers in Chumphon moved to the province from the northeastern region of Thailand. Thus, their social ties can be utilized to hire seasonal migrant laborers from that region.

Each year farmers contact laborers either via agents or through personal contacts, and informal contracts are developed before the arrival of these laborers. These contracts are not documented; rather, they are oral agreements reached between coffee farmers and northeastern laborers. Typically, the contracts cover three basic items that coffee farmers will provide for laborers: a wage, by baht per kg; transportation costs (expenses for fuel for groups of laborers to travel in their own trucks or bus fees for those who travel by bus); and temporary accommodations.

Employed laborers are also allowed to work at other coffee farms on the condition that they have already finished harvesting coffee at their contract farm. Moreover, some farmers, due to the difficulties in finding harvest labor, resort to higher payments for contract laborers to secure their harvest. Because of the limited time period for harvesting and limited supply of laborers to work on many coffee farms, most laborers look for work on resource-rich farms that can provide higher incomes.

Social ties are significant in securing seasonal harvest labor. The specific difference between coffee farms and other farms is that most coffee farmers immigrated from the northeast region in previous decades and have gained experience in growing coffee over the generations. Most of these immigrant farmers began as laborers picking coffee. They then started to settle down, purchase land, and later grow coffee themselves[21].

Social ties also work among villages. Many coffee farmers formed groups, introducing cooperatives and other enterprises in the area[22]. Nevertheless, farmers continue to maintain strong connections with their northeastern origins[21]. Thus, the connections and social support occur not only in the area they settled but also among the northeastern migrant groups because the laborers they use depend primarily on employers from their region of origin, as discussed earlier.

The strength of social relationships/networks and social capital has influenced many aspects of farmers' operations. Research on the value of Chumphon coffee networks by Homchum[22] concluded that the strong networks among coffee groups, corporations, or enterprises, affected not only farming practices and technology diffusion via the supply of information through these networks, but also created links to marketing channels.

In this case, the strength of social relationships/ networks and social capital among coffee farmers could also possibly contribute to available labor market informa-

tion. This is because the connections and mutual support in the group is likely to create cohesion and thus enable the unhindered flow and exchange of information, thus easing labor constraints. Based on the interviews conducted with farmers, under strong social relationships/networks and strong social ties, the contract laborers could also be introduced to other coffee farms after finishing their work on contract farms. This evidence of introducing labors to other farmers is also consistent with studies by Homchum[22] who showed that strong networks could also support the exchange of information among skilled laborers through informal discussions. Strong social ties among the groups and farmers also provided for the sharing of information among skilled and hard-working laborers in the area[23], this evidence may facilitate effective matching between laborers and employees. Moreover, Pokeeree, Rangsipaht and Sriboonruang[24] also supported that being in a group of coffee farmers was related to more coffee production. Regarding the selling income of coffee farmers, the payment for their products or coffee berry is based on the shipped volume for each farmer, and the cherry price is common between farmers. Even though farmers A and B join a farmers group or cooperative, they get the sales based on the price by A or B's shipped volume.

4. Methodologies

4.1 Pooled production function estimation

The estimating of pooled quadratic production function using all households' data was first analyzed. This was a practical estimation for capturing which input factors affect coffee bean production for all households. This estimation was utilized as a baseline to observe the input factors that affect the coffee production for the whole without the concerning labor constraint issue. Recently, a flexible functional form is preferred for estimating the production function. However, the translog form, which is commonly used for this type of functional form, is not appropriate for this study. Because some farmers have never hired labor from outside of the family, we observed some farms with a zero input of hired labor. The translog requires positive input observations, so we utilized the quadratic production function in this study. Our quadratic production model for identifying the factors affect coffee bean production is expressed as:

$$Y=\alpha_0+\beta_A\cdot PA+\beta_F\cdot FL+\beta_H\cdot HL+\beta_N\cdot \mathrm{NT}+\gamma_{AF}\cdot PA\times FL+\gamma_{AH}\cdot PA\times HL+\gamma_{AN}\cdot PA\times NT+\gamma_{A2}\cdot PA^2+\gamma_{F2}\cdot FL^2+\gamma_{H2}\cdot HL^2+\gamma_{N2}\cdot NT^2+\alpha_D\cdot DD+\alpha_{slope}\cdot LandSlope+\alpha_{squality}\cdot SoilQuality, \quad (1)$$

where Y is coffee production. PA, FL, HL, and NT are the inputs for planted area, family labor, hired labor (the measure of both labor inputs are recorded in man-day), and fertilizer (nutrition), respectively. In the estimation, these variables are normalized at their means. This means we estimate the normalized quadratic function. Moreover, some physical plot characteristics, such as the slope of the plot land (*Land Slope*) and soil quality (*Soil Quality*), are introduced as dummy variables, and a district dummy (DD) is included. α, β, and γ are the estimated parameters.

4.2 Augmented Inverse Propensity Weighted (AIPW) Estimator and Average Treatment Effect (ATE)

As the aim of this study is to identify the effect of labor constraints on coffee bean production, however, the simple comparisons of productivities and production between farmers are not appropriate because this constraint is not randomly assigned. As we briefly discussed in the introduction, we must consider the following issues to examine this objective. First, the scarcity of seasonal migrant labor from the northeastern region for harvesting coffee is a pervasive phenomenon in Chumphon province. However, the actual employment of this migrant harvest labor is contingent on contracts. On the labor side, the workers are concerned with their actual income based on the piece-meal rate of the picking operation. Meaning the plot conditions affecting the productivity of berries could be an important factor in drawing the contract. Second, some farmers, at times, offer better payment or accommodation to the laborers. Implying that the wealth of the farmers must be considered to understand the ease or difficulty with which they secure labor. Moreover, the farmers are concerned with information about the migrant laborers, and the social networks among villagers can be mobilized to acquire this information. This background of labor contracts with migrant harvest laborers should be considered a constraint in finding or securing harvest labor. Thus, labor must not be considered randomly assigned; rather, it is an endogenously determined phenomenon.

In order to control for these endogeneity problems of the labor constraint on coffee production in estimating its production effect, we applied the augmented inverse propensity weighted (AIPW) estimator for the normalized quadratic production function as an outcome equation. The AIPW estimator has another advantage in estimating treatment effect. It is known as double robust estimator[25, 26, 27], which requires a correct specification for either the treatment model or outcome model (not both). In other words, it enables a consistent estimation of the treatment parameters when either the outcome model, treatment model, or both are correctly specified[26, 27]. Moreover, the AIPW has been termed the "efficient influence function"[28]. The AIPW estimator has attractive theoretical properties and requires only two things be specified: (1) a binary regression model for the propensity score and (2) a regression model for the

outcome variable (two regression models, one for treatment and one for control)[27]. We applied Glynn and Quinn (2009)[27], the AIPW for the average treatment effect (ATE) is estimated as;

$$\widehat{ATE}_{AIPW} = \frac{1}{n}\sum_{i=1}^{n}\left\{\left[\frac{L_i Y_i}{\widehat{\pi}(Z_i)} - \frac{(1-L_i)Y_i}{1-\widehat{\pi}(Z_i)}\right] - \frac{(L_i-\widehat{\pi}(Z_i))}{\widehat{\pi}(Z_i)(1-\widehat{\pi}(Z_i))}\right.$$
$$\left.\left[(1-\widehat{\pi}(Z_i))\widehat{\mathbb{E}}(Y_i|L_i=1,Z_i) + \widehat{\pi}(Z_i)\widehat{\mathbb{E}}(Y_i|L_i=0,Z_i)\right]\right\}, \quad (2)$$

where L_i is the labor constraint treatment and Y_i is an outcome of coffee production. Z_i is a set of variables containing information about the probability treatment or labor constraint, and it also contains predictive information for the outcome variables. $\widehat{\pi}(Z_i)$ and $1-\widehat{\pi}(Z_i)$ are the estimated propensity scores, which are, respectively, the estimated conditional probability of the labor constraint and lack of labor constraint given Z_i. $\hat{\mathbb{E}}(Y|L)=1,Z_i)$ is the estimated conditional expectation of the outcome given Z_i within the treated group, and $\hat{\mathbb{E}}(Y|L)=0,Z_i)$ is defined analogously.

The first term of eq. (1), or $\widehat{ATE}_{IPW} = \frac{1}{n}\sum_{i=1}^{n}\left\{\frac{L_i Y_i}{\widehat{\pi}(Z_i)} - \frac{(1-L_i)Y_i}{1-\widehat{\pi}(Z_i)}\right\}$, corresponds to the basic IPW estimator, which, if it stands alone, is still widely believed to have poor small sample properties when the propensity score gets close to zero or one for some observations[27]. The second term adjusts the estimator by a weighted average of two regression estimators (more detail is provided in Glynn and Quinn, 2009).

Recently, the AIPW estimator for ATE has been applied to study the effect of adoption of farm technology or innovation on crop production in order to control for selection in terms of both treatment as a binary variable and a multivalued variable. For example, Haile et al.[25] used a double robust estimator to observation differences and found there to be a positive impact on maize yield and harvest value in Malawi. This AIPW estimator has been extended to a multivalued as multinomial logit treatment. Kikulwe et al.[29] utilized the multinomial logit model for treatment to determine the factors affecting adoption of control practices, and they employed the AIPW estimator for ATE. They found the adoption of Banana Xanthomonas Wilt (BXW) control practices had significantly impacted higher values of banana production and sales in Uganda. While, Smale[26] established an order logit for treatment of the adoption of sorghum seed on various outcomes. The author's results suggest that improved seed appears to be associated with an increased sales share.

In this study, our analysis has two components for estimating ATE. First, we specify a probit regression in order to predict treatment status or determinants of labor constraints in farm households and calculate a propensity score. Then, we conduct the outcome equation as a quadratic production function, estimated separately for each group of farms depending on their labor constraint situation (those with and without labor constraints).

We can discuss the advantages of the current AIPW approach for our research question. The first is to estimate the production function separately for each group cannot be a valid effect of the labor constraint, as discussed above. Second, another treatment effect estimation approach, such as propensity score matching (PSM), could be an alternative for our study; this depending on the specification of the treatment assignment function. However, AIPW is a double robust estimator, enabling a consistent estimation of the treatment parameters for either the outcome model, treatment model, or both are correctly specified. Our specification of the production function would be a general one; this would overcome the misspecification or omission variable problem in PSM.

4.2.1 Treatment equation for harvest labor constraints in AIPW model

The selection/treatment equation in the AIPW estimator describes the mechanism for labor constraint assignment for households. In this study, a probit model is applied to predict the treatment status or determinants of labor constraints in farm households. The covariates for the treatment model include: farmers and farm household characteristics (education of household head, ratio of farm labor per planted area, debt holding status), these variables mainly reflect farmers' endowments and a farm household's ability to hire labors. The hypotheses for the impact of the variables are as follows.

The physical conditions of the coffee plots and area, including planted area, coffee tree age, the slope of the coffee plot land, lack of water, ratio of coffee plants mixed with other crops to total coffee land are also included. Since the wage of hired laborers is paid by baht per kilogram of coffee production, plots with well-conditioned plots for picking reflect a relatively higher wage/income for laborers compared to farms with poor resources. Thus, laborers are more interested in working on resource-rich farms, which is represented in those farms' characteristics. Not only will laborers obtain more income for working on resource-rich farms but working on resource-rich farms would make the work/harvesting easier by saving time and energy, so the laborers could work more on other coffee farms, resulting in higher earnings. Thus, these farm characteristics are expected to influence labor constraints.

As discussed above, strong networks and groups formed by the coffee farmers are expected to affect the labor constraint in a positive way. These factors, including the length of time a farm household has been settled in

Chumphon province and farmers' opinions with respect to the strength of these groups in a particular area, reflect the role of social ties. Groups/communities that tend to stay united in particular areas are likely to be very cohesive, enabling the unhindered flow and exchange of information and the sharing of labor between farms. Farmers' opinions of the support from government and private organizations for coffee farms are also important factors to be included. Positive or good experiences of support from either government or the private sector could reflect valuable advice or information. The best support they experienced could also reduce labor constraints. (Details of the variables and definitions are shown in Table 3).

As we had earlier discussed the calculation of AIPW which has yielded a doubly robust property, the importance of coping with the issue of endogeneity in both (treatment and outcome) equations was one major concern. For the production function or outcome equation, the estimation could be biased if estimating the production function with the basic factor inputs such as land, labor, and current inputs (fertilizer) because we are unable to identify the difference of the coffee plot characteristics farms. However, in this estimation, we had taken into consideration of soil condition and the land slopes for controlling/regulating the difference in plot characteristics. The particular farming condition did not demonstrate any significant effect on hired labor constraint, but the social network was able to pinpoint them, as noted before. Thus, in this research study, the social ties variables (Length of time settled farm household in Chumphon province (year), farmers' opinion of the strength of the groups in the farmers' area) were also deployed in the treatment equation to elaborate on the likelihood of labor constraint. These settings in the outcome and treatment equations could contribute to risk reduction in omission variable bias problem as much as possible even when the double robust estimator was applied.

Moreover, there was another concern where social ties worked well in the estimation. That is, the spillover effect of treatment assignment is known as a violation of Rubin's Stable Unit Treatment Value Assumption (SUTVA). Actually, social networks are important for transmitting knowledge or adopting technology or variety among farmers; the production was likely to be affected by social networks. However, the harvesting was almost approaching final stage of production. After hiring the harvest labor, there was no room to spare for social networks or ties works on productivity. On the other hand, if social ties variables were not included in the selection equation, it unveils bias outcome in estimation. Thus, social ties variables were included in the selection equation, and since the harvesting season was being left at the final stage, there was no reason to be worried about the spillover effect of treatment assignment (labor constraints) or there was no possibility of violating SUTVA, which requires no spillover effects from the treatment[30)]

4.2.2 Production function in the AIPW model

The outcome equation that consists of all the factors as in a pooled quadratic production function for all households (eq.1) was conducted, estimated separately for each group of farms depending on their labor constraint situation (those with and without labor constraints) by using the AIPW approach.

Moreover, in the present context, it should be noted that Laufer's study introduced this functional form to examine the differences between the marginal productivities of male and female labor in Indian agriculture, which is a relevant previous study[31)]. Thus, we further utilized a quadratic production function to estimate the marginal productivities of family labor and hired labor to examine how farmers were coping with this harvesting labor constraint or labor allocation for coffee production as our hypothesize that farms under this constraint used family labor to compensate for the lack of available hired labor. For this purpose, a comparison in the marginal productivity of family labor and hired labor between farms with and without harvest labor constraints is useful. We followed the basic principle that the marginal productivity of inputs must be equal to the ratio of input price to output price. If there are no constraints and no market imperfections, the marginal productivity of hired labor seems to be equal to the wage and coffee price ratio. However, especially labor market imperfections are common in developing countries, and some farmers offer higher payment to meet their need for hired labor. Labor shortage constraints or higher payment/effective wage for hired labor derive the higher marginal productivity of hired labor than the farmer under no constraints. Also, if hired labor is not sufficiently available, perhaps family labor must be introduced. Specifically, we should examine if farmers mobilize their family labor to compensate for the shortage of hired labor to mitigate production; this means that the marginal productivity of family labor is likely to be lower in hired labor constraint. The comparison of marginal productivities and attained production between farmers with and without hired labor constraints provide a useful approach for understanding its effects on the outcome and farmers' coping behaviors.

5. Data collection and Survey design

This study was conducted in Chumphon province, the main province for producing Robusta coffee. The survey was carried out in mid-April until May (or after coffee harvesting had finished) of 2016. Data on total coffee households were collected from registered coffee

growing households at the Chumphon extension office as a list frame. A multistage sampling approach was applied to identify subdistricts, villages, and households. At the first stage, we purposely selected two subdistricts that produce mainly coffee, the Rubroo and Kaotalu subdistricts, which are the main hubs for coffee production; in these subdistricts, 44.7% and 24.7%, respectively, of all households produce coffee. In the second stage, we selected households from each village using proportional sampling. Finally, 160 total coffee households were selected randomly. Data were collected through a questionnaire guiding in-depth interviews with heads of coffee farms. The survey consisted of three parts. The first part collected information about the socioeconomic characteristics of farmers and farm households (sex, education, age, history of immigration, farm and nonfarm labor), household debts, and experiences of difficulties in hiring laborers. The second part of the survey collected information on the characteristics of each particular plot of the coffee farm, including water supply, land slope, soil conditions, coffee crop types (single or mixed), land use, farm production, farm income, inputs used, and especially coffee production. The last part gathered information about farmers' groups, their opinions on the role of these groups, and farmers' opinions on the group strength in their areas.

Information for all inputs, especially labors inputs used in the production functions, were collected. Participants were asked about the use of both family labor and hired labor in all activities of coffee production on the farm, including pruning, applying fertilizer, weeding, harvesting, and other activities (drying, transporting). These labor inputs are recorded in number of persons. However, both family and hired labor, in man-days, were calculated from the number of laborers multiply by the number of working days for each activity.

Thus, for family labor used in all coffee growing activities, the most intensive operation is picking coffee due to the limited period in which the berries are mature. The amount of family labor used in the harvesting period is around 114.17 man-days, while pruning the coffee branches, applying fertilizer, and weeding (applying pesticide/herbicides) took around 43.21 man-days. Other activities, like drying and transporting were asked about in relation to family labor, but these activities did not require the participation of all family members and took only a few hours a day, not the whole day. When we calculated these in man-days, they took around 47.65 man-days. Thus, the total family labor took around 205.03 man-days, or around 68 days a year. For hired labor, outside of family labor, coffee picking required the most hired labor, especially laborers from the northeast region. This was followed by applying fertilizer and pruning, but labor these jobs was mostly within the village. In total, these activities took around 140 man-days. The coffee planting area and fertilizer/nutrition inputs are recorded in area of rai and kilogram, respectively.

In order to identify the labor constraint context, farmers were asked about their experiences with hiring laborers. All farmers who were hiring, or not hiring, laborers (in the survey year 2016) were asked to identify if they could hire the amount of labor that they actually wanted to hire. Thus, the constrained households are the farms that could not hire the amount of labor that they actually wanted to hire. Unconstrained households are defined as the farms that were able to hire the amount of labor they sought. Finally, there were 121 farm households that hired laborers in the survey year (2016) and 39 farm households that did not hire laborers; the labor constraints were defined as follows:

Cell (1) and (3) of Table 2 show that there were 98 farm households (who were hiring and not hiring laborers in the survey year) that were able to hire the desired amount of outside labor. These farms are defined as the households without labor constraints. Meanwhile, 62 farm households, shown in cell (2) and (4), were unable to hire the number of laborers they sought. These farms are

Table 2. Identifies labor constraint of coffee farms households in Chumphon province

items	Farm household who hire labor (in surveying year 2016)	Farm household who do not hire labor (in surveying year 2016)	total
Farm households without labor constraints (or farms could hire the amount of labor that they actually wanted to hire)	(1) 73 households	(3) 25 households	98
Farm households with labor constraints (or farms who could not hire the amount of labor that they actually wanted to hire)	(2) 48 households	(4) 14 households	62
total	121	39	

Source: Authors' Survey

defined as the households with labor constraints.

The level of group strength was ranked on a five-point scale in order to measure the importance of networks in contributing information. A five-point scale was also used to measure farmers' opinions of government and private support on coffee farms since the role of government and private support could, hopefully, generate information that may mitigate labor constraints.

6. Estimation result

6.1 Descriptive analysis of characteristics of households with and without labor constraints

The definitions and descriptive statistics of the key

Table 3. Summary Statistics of Characteristics of household with and without labor constraint

Variables	Coffee household who has labor constraint (n=62) L=1		Coffee household who has no labor constraint (n=98) L=0		Total (n=160)		P-value
	mean	(SD)	mean	(SD)	mean	(SD)	
Dependent variables							
Labor constraint	1.00	0.00	0.00	0.00	0.39	0.49	
production of coffee (kg.)	2,886.43	3,028.05	3,357.55	3,351.11	3,174.99	3,228.26	0.0000
Explanatory variables							
Inputs							
Planted area (rai)	18.23	12.63	17.19	14.30	17.59	13.64	0.0000
Family labor (man-days)	209.90	79.93	201.90	78.14	205.00	78.69	0.0000
Hired Labor (man-days)	137.37	137.88	142.98	163.20	140.81	153.45	0.0000
fertilizer used (chemical and bio fertilizer) (kg/rai)	2,089.68	2,063.70	2,361.22	2,274.85	2,256.00	2,192.84	0.0000
Coffee farmer's characteristics							
Education of household head (dummy variable, 0 = no education or primary, 1 = higher than primary school)	0.21	0.41	0.30	0.46	0.26	0.44	0.0023
Debt holding status (1= farmers have a not completely repaid debt at the time of the survey, 0= otherwise)	0.85	0.36	0.72	0.45	0.78	0.42	0.0000
Length of time settled farm household in Chumphon province (year)	23.65	8.79	25.22	8.83	24.61	8.82	0.0000
Coffee farms' characteristics							
Coffee age tree (year) (maximum age)	21.32	7.34	21.09	8.00	21.18	7.73	0.0000
Land slope (0= flat land, 1= otherwise (hill and deep slope)	0.85	0.36	0.86	0.35	0.86	0.35	0.0000
Lack of water (water scarcity) (1= lack of water, 0= otherwise)	0.45	0.50	0.20	0.41	0.30	0.46	0.0565
Ratio of coffee plants mixed with other crops to total coffee land	0.82	0.38	0.79	0.39	0.80	0.38	0.0000
Soil quality (1=good quality, 0 = otherwise)	0.25	0.43	0.22	0.42	0.23	0.42	0.0024
Farmers' opinion of strong of the groups in farmers' area (0= not strong, 1= relatively strong, 2=somewhat strong, 3 = undecided or neutral, 4=moderately strong, 5=extremely strong)	2.48	1.16	3.09	1.21	2.86	1.22	0.0000
Farmers' opinion of supporting from government and private on coffee farms (0= not satisfy, 1= relatively satisfy, 2=somewhat satisfy, 3 = undecided or neutral, 4=moderately satisfy, 5=extremely satisfy)	3.95	1.06	3.76	1.04	3.83	1.05	0.0000
Dummy Rubroo subdistrict (1= Rubroo subdistrict, 0= otherwise)	0.76	0.43	0.68	0.47	0.71	0.45	0.0000

Source: Authors' survey
Note: 1 rai = 0.16 hectare

variables used in the estimation are shown in Table 3. The average coffee output for farms that have no labor constraints was 3,357.55 kg., which is higher than the 2,886.43 kg. generated by farms that have labor constraints. For the inputs used, on average, farms without labor constraints have a greater man-day for hired labor (142.98 man-days), and used more fertilizer (2,361.22 kg.), while labor constrained farms depend more on family labor (209.9 man-days) and have slightly larger planted areas (18.23 rai). About 30% of respondents without labor constraints had obtained a higher than primary school degree, and this percentage is higher than 21% for labor constrained farms. In addition, 85% of farms with labor constraints still have debt, which is a greater percentage than farms without labor constraints (72%). Further, 45% of labor constrained respondents faced a lack of water supply to equip their farms, compared with 20% or less for unconstrained farms. In terms of opinions, farmers without labor constraints have a stronger relationship with groups in their area.

6.2 Result of the production function of total households

Before estimating the production function for each group by using the AIPW approach, the production function for all samples was estimated, the result is shown in Table 4. Better soil quality is also a significant effect on coffee production. Coffee farms in Rubroo subdistrict, the main area of coffee production, soil quality also significantly affect coffee production, and still has the main effect on the coffee product. However, to derive the actual production effect of each input, the marginal productivity at mean was derived, as shown in Table 5. The marginal productivities of three inputs on coffee production, planted area, hired labor, and fertilizer had a positive and were significant. The marginal productivity of family labor was not significant.

Table 4. Estimation Results of quadratic production function of all households

variables	Coffee production of total households	
	coefficient	S.E.
inputs		
Planted area	0.097	0.315
Family labor	0.604	0.496
Hired labor	0.303	0.188
Fertilizers	**0.595****	**0.291**
Planted area* Family labor	0.182	0.270
Planted area* Hired labor	**0.309****	**0.129**
Planted area* Fertilizers	**0.225****	**0.108**
Family labor * Hired labor	-0.069	0.175
Family labor * Fertilizers	-0.017	0.221
Hired labor* Fertilizers	**-0.186***	**0.095**
Squared Planted area	-0.197	0.154
Squared Family labor	-0.257	0.208
Squared Hired labor	-0.029	0.042
Squared Fertilizers	**-0.121****	**0.047**
Soil quality	0.199**	**0.093**
Land slope	0.084	0.115
Rubroo (subdistrict dummy)	**0.204****	**0.093**
Intercept	-0.595*	0.317
Adjusted R-squared: 0.7811		

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$
Source: Authors' estimation

Table 5. The marginal Productivity at mean of each inputs

Input	Marginal Productivity (MP)	S.E.
Planted area	75.828***	21.858
Family labor	2.865	2.095
Hired labor	6.732***	1.718
Fertilizers	0.529***	0.158

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$
Source: Authors' estimation

6.3 AIPW estimation

However, our concern focused on the difference in the marginal productivity of hired labor and family labor between farmers with and without hired labor constraints. Table 6 provides the estimated result of AIPW for this concern. The result of the probit model with determinants of labor constraint is shown in the first column of Table 6. This selection equation highlights that holding debt is an obstacle to hiring labor. Farmers with debt may have less ability to pay for hired labor and maybe have a lack of cash flow. Thus, they might offer fewer options for laborers compared to those who have no debt. Farms with a lack of water resources are also more likely to have labor constraints.

As we expected, the role of strong social ties seems very important in determining the labor constraints of farm households. Both a longer length of time settled in Chumphon province and stronger farmers' groups increase the probability of having no labor constraints. A longer time being settled in Chumphon province implies that farmers have tighter or stronger connections with the local people and local communities as well as more experience in dealing with northeastern labor, greater trustworthiness in terms of sharing labor with local people, or sharing

Table 6. Estimation Results of AIPW Model

Equations	Selection equation		Outcome equation for farmer who has hired labor constraint		Outcome equation for farmer who has no hired labor constraint	
Dependent variables	Labor constraint (1/0)		Coffee production (kg.)		Coffee production (kg.)	
	coefficient	S.E.	coefficient	S.E.	coefficient	S.E.
Labor constraint (1/0)						
Education of household head	-0.333	0.254				
Debt holding status	**0.856****	0.295				
Length of time settled farm household in Chumphon province	**-0.029***	0.013				
Farmers' opinion of strong of the groups in farmers' area	**-0.280****	0.103				
Farmers' opinion of supporting from government and private on coffee farms	-0.034	0.112				
Planted area	-0.009	0.009				
Coffee age tree	0.005	0.015				
lack of water	**0.8493****	0.260				
Ratio of coffee plants mixed with other crops to total coffee land	0.143	0.312				
Land slope	0.012	0.343	-0.115	0.203	0.143	0.129
Rubroo (subdistrict dummy)	0.074	0.250	0.133	0.164	**0.324****	0.113
inputs						
Planted area			-0.059	0.591	**0.848***	**0.397**
Family labor			-1.361	0.999	**1.492****	**0.557**
Hired labor			0.085	0.474	0.038	0.209
Fertilizers			**1.077***	**0.633**	0.295	0.364
Planted area* Family labor			0.682	0.533	-0.301	0.343
Planted area* Hired labor			0.659	0.520	0.199	0.163
Planted area* Fertilizers			-0.396	0.573	0.656*	0.272
Family labor * Hired labor			-0.185	0.408	0.059	0.199
Family labor * Fertilizers			0.272	0.599	0.165	0.277
Hired labor* Fertilizers			0.153	0.453	0.001	0.119
Squared Planted area			-0.381	0.309	**-0.396***	**0.224**
Squared Family labor			0.250	0.465	**-0.588****	**0.223**
Squared Hired labor			-0.145	0.273	-0.047	0.042
Squared Fertilizers			**-0.254****	**0.087**	**-0.392****	**0.139**
Soil quality			**0.324***	**0.165**	0.137	0.107
Intercept	0.353	0.896	0.609	0.598	**-1.136****	0.367

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

labor constraint (1= Coffee household that has a labor constraint, 0= Coffee household that has no labor constraint), n=160.

Source: Authors' estimation

contract laborers with other coffee farms, thus reducing labor constraints. Additionally, stronger farmers' groups enabled the unhindered exchange of information. When strong social relationships/networks and strong social ties are present, the contract laborers could also be introduced to other coffee farms after finishing their work on the contracted farm, and this could ease labor constraints.

The result of the second component/outcome equation of the quadratic production function for both for the treated (labor constrained households) and control (unconstrained labor households) groups are shown in the second and third columns of Table 6, respectively. Mainly, the quantity of fertilizer used seems to significantly affect coffee production both linearly and quadratically for households with labor constraints. Good soil quality is also significantly affected in coffee production. However, linearly and quadratically terms for farms with no labor constraints showed planted area, farm labor, and fertilizer significantly affect coffee production. In addition, the coffee farms in Rubroo subdistrict, the main area of coffee production, also significantly affect coffee production. The result also clarified that the planted area and fertilizer used interaction is non-negligible. The positive interaction of planted area with fertilizer used could explain that additional coffee grows in planted areas that use fertilizer, thereby increasing coffee production. In order to derive the actual production effects of two types of labor inputs, the marginal productivities must be derived.

6.4 Average treatment effect of labor constraint on production

Finally, estimates of the average treatment effect (ATE) for coffee production outcomes for the three estimators are shown in Table 7. The results show that of all the estimators, the AIPW estimator provides more significant results with either sandwich or asymptotic standard error. Based on these results, therefore, the impact of labor constraints on outcomes is interpreted using the AIPW estimator. The effect of labor constraints on coffee production is clearly shown to be negative and statistically significant by the AIPW estimators.

6.5 Marginal productivities of labor

The marginal productivities of labor, and their confidence intervals, result from unitizing the production model to explain the labor allocation between family and hired labor, as shown in Table 8. These productivities were estimated at the mean observations for each group with/without labor constraints. Showing the marginal productivities of hired labor for the treatment group (labor constrained farms) were higher than the control group (unconstrained farms). This implies the farmers who faced hired labor constraints introduce less (but insignificant) hired labor in their production compared to farmers under no hired labor constraints. The marginal productivity of the family labor for the treatment group was lower than that for the control as we hypothesized. However, the marginal labor productivities between the two groups of farmers were not significantly different. It could not support the hypothesis that farmers mobilize their family labor to compensate for the shortage of hired labor.

7. Discussion

The result of the ATE, found by employing AIPW, clearly showed that labor constraints had a negative and statistically significant effect on coffee production. However, the marginal productivity results from the quadratic

Table 7. Average treatment effect, coffee labor constraint.

estimators	ATE (Coef.)	SE sandwich	T value	SE asymptotic	T value
AIPW	-0.285	0.136	-2.101	0.118	-2.428
	-0.292			0.118	-2.487
IPW Regression	-0.174			0.117	-1.488

Source: Authors' estimation by using R package "CausalGAM" (Glynn and Quinn, 2009)

Table 8. Marginal Productivities of Labors derived from quadratic production function

Inputs	Constraint household				No constraint households			
	Marginal productivity	SE	confidence interval 2.5%	97.5%	Marginal productivity	SE	confidence interval 2.5%	97.5%
Family labor	-1.21	3.77	-8.59	6.17	3.96	2.55	-1.05	8.97
Hired labor	8.89	4.21	0.63	17.15	4.79	2.03	0.81	8.78

Source: Authors' estimation

production function revealed a difference in the marginal productivity of the labors inputs was not significant, or farmers mobilizing their family labor to compensate for the shortage of hired labor was not different between the two groups of farmers. This could discuss that the farmers with labor constraints still had another constraint for mobilizing family labor; they were unable to completely mitigate the effect of the hired labor constraint.

The livelihood of coffee farms in Chumphon province are based on coffee production operations. These operations face the severe problem of labor shortages, especially for picking coffee—a time when these farms depend on seasonal labor from the far northeast region to supplement family labor. The development of the northeast region in Thailand has decreased the agricultural labor force. Thus, there are fewer laborers who want to work on coffee farms. Moreover, the cost of transportation and accommodation for laborers as well as the pay provided by coffee farmers may increase in the future. Therefore, the issue of labor constraints needs to be emphasized so that programs or strategies to cope with the serious consequences are included in the government plan for the coffee industry and implemented.

Coffee production is a key indicator of the income of coffee farmers, and labor constraints are shown to reduce production—even when family labor is fully used. Moreover, it will be difficult to rely on laborers from northeast Thailand in the future. The exchange of labor information and sharing data of labor employed from other crop activities was needed to cope with the labor shortage for harvesting coffee. For example, rubber tapping laborers in the study area normally work through the night and are available to harvest coffee beans during the fruiting period. However, labors working in other crop activities may lack the skills for harvesting coffee. As a result, providing information on coffee picking practice on the site is needed. Additionally, the exchange of labor information through social ties and stronger group activities is also important. As shown by the probit result, the key element of social ties and stronger group activities are also important to reducing the probability of labor constraints. Thus, one policy recommendation is that knowledge or technological diffusion, not only related to farm practices but also labor information, can be transferred via coffee groups, cooperatives, and enterprises, growing a community of practice among coffee farms will also help to increase coffee productivity.

Moreover, even though there are no mechanical harvesting methods applied by small and larger farms for picking coffee beans, technology or tools for analyzing coffee bean's integrity is required. Such as color separation and coffee bean maturity are used as appropriate indicators for harvesting coffee for laborers who lack analytical skills or experience in harvesting coffee. This will be beneficial not only for saving harvesting time but also for improving harvesting quality. Therefore, collaborations among local and national research institutes, universities, and stakeholders from government and non-government organizations can develop those technologies.

Conflict of interest

There is no conflict of interest.

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タイ王国チュンポン県におけるロブスタコーヒー生産農家が直面する収穫労働制約が生産に及ぼす影響

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要旨

本研究は、タイ南部のチュンポン県のコーヒー栽培農家が近年直面している収穫労働の確保の困難性が生産に及ぼす影響を数量的に検証した。同地域では、もともと東北部から移り住んできた人々がコーヒー生産を担っており、収穫時期に必要となる労働力についてはこれまで東北部からの出稼ぎ労働力に頼ってきた。本研究は、この労働制約の起こりやすさはランダムなものではなく各農家の労働需要や収穫作業条件によって決まることを踏まえて、また雇用労働制約の有無による農家の対応をみるために、二重にロバストなAIPW推定量によってquadraticな生産関数を推定し、雇用労働制約の有無の違いによる家族労働と雇用労働の限界生産性を比較することで、雇用労働制約がある場合の家族労働の補完的な投入の程度について検証した。結果、雇用労働制約の有無によって有意な限界生産性の差は見られないものの、雇用労働制約が有ることで有意に生産量が低くなることがあきらかとなった。

キーワード：労働制約，拡大された逆傾向重み付け推定量，ロブスタコーヒー，タイ王国