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Can crop diversification of perennial crop by smallholder farmers explained by risk attitudes and time preferences?

Arieska Wening Sarwosri, Oliver Musshoff

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Abstract

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1. INTRODUCTION

Risk attitudes and time preferences are crucial for farmers' decision making (Falk *et al.,* 2018). For instance, farmers' risk attitudes influences technology adoption such as high yield variety crops, drought tolerant plants (Feder, 1980; Holden and Quiggin, 2017), and new farming systems, *e.g.,* conservation agriculture (Ngwira *et al.,* 2013). Risk attitudes are also utilised to explain farmers' decision of crop diversification (Hellerstein *et al.,* 2013).

Crop diversification is the practice of cultivating two or more crops at the same time. Crop diversification helps to reduce income risks by creating more than one source of income. Crop diversification can also provide external benefits such as: (1) supporting non-chemical pest management (Theunissen, 1994), and (2) promoting biodiversity such as in the bird population (Henderson *et al.,* 2009). Based on the existing literature, the relationship/dependency between risk attitudes and crop diversification are diverse. On the one hand, Chavas and Di Falco (2012) and Bezabih and Sarr (2012) found that risk aversion increases the likelihood of deciding to diversify crops using a sample of Ethiopian farmers. On the other hand, Hellerstein *et al.* (2013) found more risk-averse farmers are less likely to diversify crops among farmers from United States. Moreover, the existing literature investigating a relationship/dependency between risk attitudes and crop diversification is incomplete. To date the literature has investigated crop diversification of seasonal and/or annual crops, *e.g.,* Bezabih and Sarr (2012); Chavas and Di Falco (2012); Dercon (1996); Hellerstein *et al.* (2013). However, a research gap has emerged concerning crop diversification of perennial crops. Thus, those studies' findings cannot be transferred to perennial crops because they have different types of risks. Perennial crops are more susceptible to diseases because crop rotation and fallow periods cannot be carried out to prevent the spread of disease (Cox, 2004).

Furthermore, time preferences come into consideration when farmers deal with perennial crops, due to the long gap between planting and harvesting (Sauter and Mußhoff, 2018). The time preferences are quite pertinent given that cultivating perennial crops comes with long-term consequences for farmers. For instance, perennial crops require farmers to wait for several years before obtaining the first yields. The investment in perennial crops also affects household incomes for many years. Perennial crops have different types of time consideration. For example: (1) cultivating perennial crops associates to the possibility of suffering from future climate change (Lobell, 2006), (2) perennial crops have longer period of zero income between seed planting and the first harvest than seasonal/annual crops. Accordingly, these long-term returns from perennial crops underscore the importance of farmers' time preferences concerning decision making. However, it is also not clear from the literature how time preferences influence crop diversification, especially for perennial crops.

To the best of our knowledge, one existing study examines crop diversification between one annual and one perennial crop is Bocqueho and Jacquet (2010)[1]. They found that risk aversion hinders diversification but did not analyse the effect of time preferences. Thus, the relationship/dependency between farmers' time preferences and diversification of perennial crop has not yet been investigated.

To fill this research gap, we investigated risk attitudes and time preferences of farmers who cultivated one single perennial crop and compared it with the preferences of farmers who cultivated two different perennial crops. The study took place in Sumatra Island, Indonesia, where rubber has been the most important cash crop since the beginning of the 19th century (Casson and Obidzinski, 2002). Rubber has been planted throughout generations and has become a cultural cash-crop (Feintrenie and Levang, 2009; Gatto *et al.,* 2015). In 1980, the government introduced oil palms and hence, opened an opportunity for farmers to cultivate them besides rubber. Gatto *et al.* (2017) observed that oil palm plantations started to be established by smallholder farmers around 1992.

The study involved 636 Indonesian smallholder farmers. We included two groups of farmers: (1) farmers who cultivated only rubber, and (2) farmers who cultivated rubber and oil palm trees. Oil palms were cultivated after rubber and the average size of oil palm farms was relatively smaller than rubber farms. Thus implied that crop diversification of the two crops was being performed (Euler *et al.*, 2017; Feintrenie *et al.,* 2010). We estimated the risk attitudes and time preferences experimentally. A Holt and Laury task (HL-task; Holt and Laury, 2002) was used to elicit risk attitudes, and a Coller and Williams task (CW-task; Coller and Williams, 1999) was conducted to examine time preferences by estimating the individuals discount rate of the decision makers. The HL-task and CW-task have been used in several studies involving rural people and farmers in particular (Holden and Quiggin, 2017; Ihli *et al*., 2016; Tanaka *et al.,* 2010). Both tasks were incentivised, *i.e.,* payouts were given for each of both tasks, to encourage sensible and realistic decisions of the participants during the experiments (Hertwig and Ortman, 2001). We applied the joint-estimation method by Andersen *et al*. (2008) where risk attitudes are considered when estimating the discount rate.

This study contributes to the body of literature in two ways. First, this study investigates the relationship/dependency of risk attitudes and time preferences on crop diversification involving farmers within the Asian context, *i.e.,* Indonesia. So far, the previous studies investigating the influence of risk attitudes and time preferences on the decision to diversify crops have mostly been conducted in high-income countries (Hellerstein *et al.,* 2013) or in African countries (Bezabih and Sarr, 2012; Chavas and Di Falco, 2012; Dercon, 1996). Besides, involving Indonesian farmers in the experiment also provides a unique feature of the sample, because the farmers either cultivate one or two perennial crops. This is somehow different to the western context, where almost all farmers focus on annual crops and produce various types of crops. Furthermore, the existing studies do not focus merely on crop diversification of two perennial crops. Thus, the second contribution of this study is examining influence of risk attitudes and time preferences with focus on crop diversification of perennial crops.

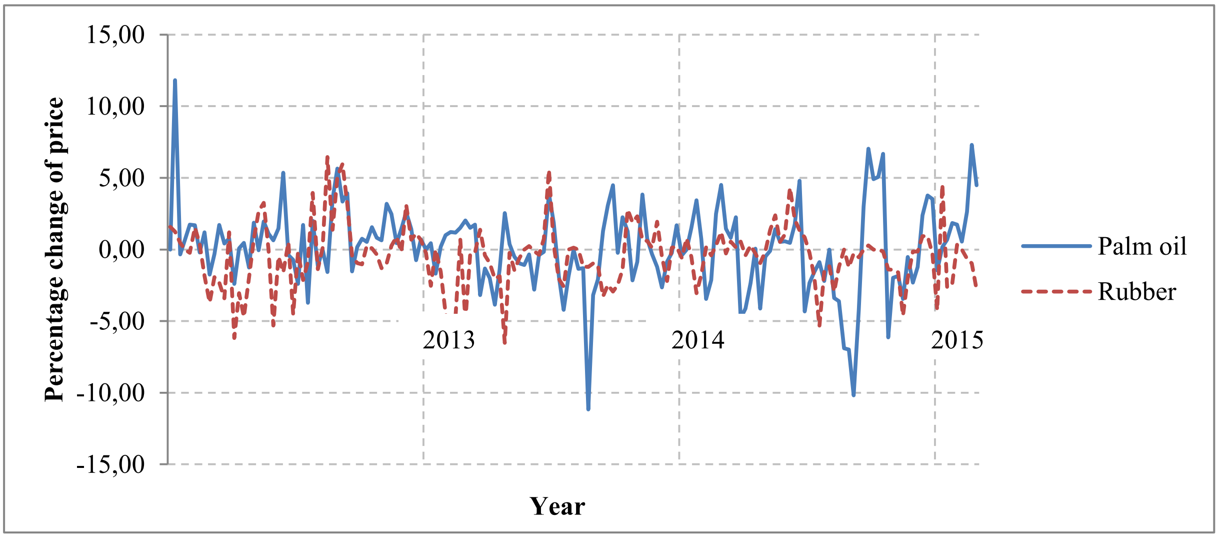
The structure of the paper is as follow: Section 2 presents the derivation of the hypotheses. The HL-task and CW-task, the estimation method, and the sample selection are explained in Section 3. Section 4 presents the descriptive statistics, results and discussions. Finally, Section 5 provides the conclusions of the study.

2. DERIVATION OF HYPOTHESES

Initially, rubber was the most important cash-crop in Sumatra until the period when the transmigration programs promoted more intensive farmland use and introduced oil palms (Feintrenie and Levang, 2009; Gatto *et al.,* 2015). In the beginning, oil palm plantations were established by the government and private companies and were subsequently planted by farmers as well (Drescher *et al.,* 2016; Gatto *et al.,* 2017). Since then, Sumatra Island is not only the largest rubber producer in Indonesia but also has become the central area of palm oil production. Even though rubber remains the dominant cash crop and greater number of farmers cultivate rubber. The proportion of farmers cultivating both crops at the same time is also high (Euler *et al.,* 2017; Gatto *et al.,* 2015). We formulated two hypotheses regarding the risk attitudes and the time preferences of farmers on the one hand and crop diversification on the other hand based on a literature review and a secondary dataset.

2.1.Risk attitudes of the farmers and crop choice

The weather is an important risk factor in agriculture (Lien and Hardaker, 2001), for example, drought and other cases of extreme weather can substantially diminish farmers' incomes (Turvey and Kong, 2010). The weather influences rubber production in two possible ways. First, the yield of rubber depends on precipitation. The harvest of latex is conducted every day, where farmers remove the bark and let the latex flow down along the tree trunk to be collected in a cup. The latex inside of the cups is collected in the afternoon or on the following day in a bigger container. Therefore, rainwater reduces and/or circumvents yield because the latex leaks out from the cups (Feintrenie *et al.,* 2010). Secondly, low humidity causes rubber trees produce less latex (Miyamoto, 2006). In contrast, oil palm trees are less affected by the weather and hence, the harvest can be conducted year-round (Rist *et al.,* 2010).



Sources: The price of rubber from GAPKINDO, the price of oil palm fruits from the weekly meeting of the Ministry of Agriculture at province level

Figure 1. Percentage change of weekly price for oil palm fruits and rubber at farm-gate

Price fluctuations are further important risk factor in agriculture (Aimin, 2010). To observe the price fluctuation of oil palm fruits and rubber in farm-gate, we obtained a dataset of weekly price for the years 2013 to 2015[2]. The price fluctuation of both crops is illustrated in Figure 1. Visually, the farm-gate price of oil palm fruits fluctuates more than the rubber price. In addition, following Gilbert and Morgan (2010) calculation for price volatility of agricultural products, the estimated price volatility of rubber was 15.76% and the price volatility of oil palm fruits in farm-gate was 21.28%.

weather dependency, while the price of oil palm fruits at farm-gate is more volatile (Feintrenie *et al.,* 2010; Miyamoto, 2006; Rist *et al.,* 2010). To formulate a hypothesis regarding risk attitudes, we refer to the portfolio concept (Markowitz, 1952) which explains that every investment has expected return and variances. According to the portfolio concept, the variance of investment can be reduced by diversifying the investments, even though each of the different investments has its own variance. Indeed the diversification cannot eliminate all of the potential variances from the investments, but it provides maximum expected returns with minimum variances (Markowitz, 1952). The diversification effect could occur if farmers mix different activities, *i.e.,* cultivate more than one crop, as so-called crop diversification

(Dercon, 1996; Heady, 1952; Pellegrini and Tasciotti, 2014). The benefits of crop diversification have been discussed in the literature (*e.g.,* Heady, 1952). The portfolio effect occurs if the correlation coefficient between the expected returns of both investments is less than one and ideally negative. Using the price data (cf. Figure 1), information of farmers' productivities[3], and plantation areas; we can estimate expected average weekly returns and compute the correlation coefficient of the expected returns from both crops. The expected returns of both crops are not perfectly correlated (correlation coefficient is 0.31), suggesting that cultivate both crops can allow the farmers to stabilize their income. Therefore, risk-averse farmers have an incentive to cultivate rubber and oil palms together. Accordingly, the first hypothesis can be formulated as: *more risk-averse farmers cultivate oil palms besides rubber.*

2.2.Time preferences of the farmers and crop choice

The cultivation of oil palms has the characteristic of a shorter waiting time before the first harvest compared to rubber. The first harvest of oil palm trees starts in the fourth year after planting (Corley and Tinker, 2016). Oil palm trees can be harvested up to the age of 25 years. In contrast, the rubber farmers have to wait for seven years for the first harvest and can obtain yields from the trees up to the age of 30 to 35 years (Woittiez *et al.,* 2017). Even though oil palm trees have a shorter waiting period for the first harvest, the annual expected returns per hectare of land and the expected total returns on a full cycle of rubber plantations are higher, on average (Feintrenie *et al.* 2010).

Individuals with high discount rate would prefer to receive an earlier payoff even if it is smaller than a later payoff (Coller and Williams, 1999) and farmers are characterized as individuals with high discount rate (Lawrance, 1991). The cultivation of oil palms generates earlier income from the first harvest than rubber, but the expected returns of oil palm plantation are lower. Thus, rubber farmers with a higher discount rate may diversify their plantation by cultivating oil palms, instead of expanding their rubber plantations. Therefore, the second hypothesis can be formulated as: *farmers with higher discount rate cultivate oil palms besides rubber*.

3. METHODOLOGY

3.1.HL-task

For the elicitation of the risk attitudes, we carried out an incentivised HL-task using the Multiple Price List (MPL), where the participants were confronted with a series of ten paired lotteries. Within the series of lottery choices, the chances of obtaining a high payoff are gradually increasing with each of the consecutive lottery pairs as presented in Table 1. Each paired lottery consists of two options: option *A* and option *B* and there are two payoffs for every option: a high and a low payoff. The two payoffs in option *A* are 4,000 Indonesian Rupiah (IDR) and 3,200 IDR, and the payoffs in option *B* are 7,600 IDR and 200 IDR[4]. The difference between the high and low payoff in option *A* is less compared to the difference of payoffs in option *B*. Thus; option *A* is a safe-option and option *B* is a risky-option. In each row, the participants must make one choice, choosing option *A* or option *B*. When the probability of the high payoff is low, then the participants should choose option *A* and switch to option *B* when the probability to obtain the high payoff is increasing (Holt and Laury, 2002). The row where the participants switch from option *A* and switch to option *B* implies the respective risk attitudes of the participants.

During the data collection, the HL-task was visualized following Ihli *et al.* (2016) to help the farmers understand the task. We displayed images of balls with four different colors inside of two closed bags to depict the payoffs: red and yellow represented the high and low payoffs in option *A*, while green and blue visualized high and low payoffs in option *B*. In each row, the proportions of colored balls change according to the probabilities. For example, in row 1, bag A contains one red ball and nine yellow balls, while bag B contains one green ball and nine blue balls. In row 2, bag A contains two red ball and eight yellow balls, while bag B contains two green ball and eight blue balls; and so on until row ten (example of how we presented the MPL to the participants is in the Appendix).

Table 1. Multiple price list of the HL-task[a]

Row	Option *A*	Your choice	Option *B*	Expected payoff difference
1	10% of 4,000, 90% of 3,200	…	10% of 7,600, 90% of 200	2,340
2	20% of 4,000, 80% of 3,200	…	20% of 7,600, 80% of 200	1,680
3	30% of 4,000, 70% of 3,200	…	30% of 7,600, 70% of 200	1,020
4	40% of 4,000, 60% of 3,200	…	40% of 7,600, 60% of 200	360
5	50% of 4,000, 50% of 3,200	…	50% of 7,600, 50% of 200	-300
6	60% of 4,000, 40% of 3,200	…	60% of 7,600, 40% of 200	-960
7	70% of 4,000, 30% of 3,200	…	70% of 7,600, 30% of 200	-1,620
8	80% of 4,000, 20% of 3,200	…	80% of 7,600, 20% of 200	-2,280
9	90% of 4,000, 10% of 3,200	…	90% of 7,600, 10% of 200	2,940
10	100% of 4,000, 0% of 3,200	…	100% of 7,600, 0% of 200	-3,600

Notes: [a]The amount of payoff is in IDR.

3.2.CW-task

We employed an incentivised CW-task to elicit the time preferences. Coller and Williams (1999) elicited time preferences by confronting participants with two options for payoffs: option *I*, earlier-smaller payoff, and option *II*, later-higher payoff. We adopted this design and modified some specific elements to provide a feasible design of the task. In our design, option *I* is a payoff in a week (seven days) for which the payoff amount is fixed at 50,000 IDR[5]. We applied front delay in option *I* for one week to reduce participants' temptation to obtain a "today" gain, hence, a present bias was avoided (Andersen *et al*., 2008). Likewise, this front delay was also meant to hold the transaction cost for participants remains constant, *i.e.,* taking payouts with uncertainty of reliability for receiving the payouts in the future (Laury *et al.,* 2012). Option *II* was a payoff in three months (90 days). The values of payoffs in option *II* were not constant but increasing along the ten rows of the matrix payoff in Table 2 depending on the amount of the annual interest rates. We set the 90 days delay for the option *II* according to two reasons: (1) 90 days delay was previously used in the literature (*e.g.,* Hermann and Musshoff, 2016; Laury *et al.,* 2012), and (2) too long waiting period for the option *II* would create difficulties in the distribution of the payouts for monetary incentives. The payouts were not offered in cash, but instead, shopping vouchers for daily groceries were handed to each smallholder[6]. The shopping vouchers could be used in a particular local shop in the villages. Thus, not too long waiting period of option *II* helps to anticipate complexities of maintaining and monitoring the local shops for exchanging the shopping vouchers. The interest rates range from 10% to 100%. In every row, the participants must choose one option (option *I* or option

II). The participants' range of discount rate is determined based on the point when the participants switch from option *I* to option *II* at the first time.

Table 2. Payoff matrix of CW- task[a]			
Row	Option *I* (in seven days)	Your choice	Option *II* (in 90 days)
1	50,000	…	51,300
2	50,000	…	52,500
3	50,000	…	53,800
4	50,000	…	55,200
5	50,000	…	56,500
6	50,000	…	57,900
7	50,000	…	59,300
8	50,000	…	60,700
9	50,000	…	62,000
10	50,000	…	63,600
Notes: [a]The amount of payoff is in IDR.			

3.3.Monetary incentives

The monetary incentives were provided for both tasks to encourage sensible and realistic decisions of the participants (Hertwig and Ortman, 2001). There were two steps to determine the payouts in the HL-task: (1) participants took out one of ten numbered-coins from a closed bag. The chosen coin showed one randomly selected row out of the ten row of the HL-task, for which the incentive was given. (2) Based on the determined row, the participants could draw one ball from bag A or bag B depending on their choice as written down in the questionnaire sheet. The value of the shopping voucher depended on the colour of ball drawn. For example, if the participants took a red ball from bag A, then, they received a shopping voucher with the value of 4,000 IDR.

There was only one step to determine the value of the payouts in the CW-task, in which the participants took one out of ten numbered-coins from a closed bag. The chosen coin defined the selected row, where the value of the payouts was determined (depending on participants' choices, option *I* or *II*). If the payout was selected from option *I*, they received 50,000 IDR and could use the shopping voucher on the seventh day after the experiment. If the payout was selected from option *II*, they could use the shopping voucher on the ninetieth day after the experiments which had a value depending on the selected row[7].

3.4.Joint-estimation method

Following Andersen *et al*. (2008) study, we utilised the joint-estimation method, where risk and time preferences of participants are estimated simultaneously. Therefore, risk attitudes are integrated for the estimation of the discount rate. To conduct the estimation, Andersen *et al*. (2008) utilised the maximum likelihood and assumption of a power risk-utility function with constant-relative-risk-aversion (CRRA) (Holt and Laury, 2002):

$$U(X) = \frac{(X + \omega)^{1-\theta}}{1 - \theta} \qquad (1)$$

Where U is the utility, X are the payoffs in the HL-task, θ is the risk aversion coefficient, and ω is the background consumption. We assumed the ω is equal to zero as in Andersen *et al*.

(2008), therefore, we do not considering the background consumption in further equations. If j indicates the row in the HL-task, then let the high payoff be denoted as h with the respective probability p_j, and the low payoff as l with the respective probability as $1 - p_j$. Thus, X_{Ah} indicates the high payoff and X_{Al} indicates the low payoff of option A. X_{Bh} indicates high payoff and X_{Bl} indicates low payoff of option B. Then the expected utility (EU) of the paired lotteries for option A and B of the HL-task can be formulated as (Andersen *et al.*, 2008):

$$EU_{Aj} = p_j \cdot U(X_{Ah}) + (1 - p_j) \cdot U(X_{Al}) \tag{2}$$

and

$$EU_{Bj} = p_j \cdot U(X_{Bh}) + (1 - p_j) \cdot U(X_{Bl}) \tag{3}$$

To allow for randomness of the participants' choices during the experiment, Holt and Laury (2002) introduced a noise parameter (μ), the so-called Luce's error (Luce, 1959). Let the probability to choose option A or B in row j of HL-task be denoted as Pr_j^{HL}. Hence, the probability of choosing option A is as follows (Holt and Laury, 2002):

$$Pr_j^{HL}(A) = \frac{EU_A^{\frac{1}{\mu}}}{EU_A^{\frac{1}{\mu}} + EU_B^{\frac{1}{\mu}}} \tag{4}$$

The probability of choosing option B is analogue to equation (4). The participants' decision to select one option is denoted as y_j, where $y_j = A$ if the participants chose option A and $y_j = B$ for the choice of option B. Finally, the log likelihood of the HL-task (L^{HL}) can be formulated as (Andersen *et al.*, 2008):

$$\ln L^{HL}(\theta, \mu; y, Z) = \sum_j ((\ln(Pr_j^{HL}(A) | y_j = A) + (\ln\left(1 - Pr_j^{HL}(A)\right) | y_j = B)) \tag{5}$$

The vector of the household characteristics was denoted as Z. The estimation of the risk attitudes involving household characteristics was carried out for robustness check.

Furthermore, the risk attitudes of the participants were incorporated for the estimation of the discount rate. To do so, we first integrated the coefficient for risk attitudes into the present value of the payoffs in the CW-task:

$$PV_I = \left(\frac{1}{1+\delta}\right)^t \cdot \frac{(M_I)^{1-\theta}}{1-\theta} \tag{6}$$

and

$$PV_{II} = \left(\frac{1}{1+\delta}\right)^{t+\tau} \cdot \frac{(M_{II})^{1-\theta}}{1-\theta} \tag{7}$$

PV_I is the present value of option *I* presented in the CW-task and PV_{II} is the present value of the option *II*. M_I is the payoff of option *I* in time $t = 7\ days.$ M_{II} is the payoff of option *II*, in time $t + \tau = 90\ days$. Thus, τ is the time between the early and later payoffs, *i.e.,* 83 days. δ indicates the discount rate. ϑ is the noise parameter for the estimation of the discount rate. The probability of the participants to choose option *I* or *II* in the row k of CW-task is denoted as Pr_k^{CW}, then the probability of a smallholder to choose the option *I* in row k can be defined as (Andersen *et al.*, 2008):

$$Pr_k^{CW}(I) = \frac{PV_I^{\frac{1}{\vartheta}}}{PV_I^{\frac{1}{\vartheta}} + PV_{II}^{\frac{1}{\vartheta}}} \tag{8}$$

The participants' decision of selection was denoted as y_k. Thus, $y_k = I$ if the participants chose option I and $y_k = II$ for the choice of option II. With the integration of the risk attitudes, the log likelihood of the discount rate estimation was formulated as:

$$\ln L^{CW}(\theta, \delta, \mu, \vartheta; y, Z) = \sum_k ((\ln(Pr_k^{CW}(I)|y_k = I) + (\ln\left(1 - Pr_k^{CW}(I)\right) | y_k = II)) \quad (9)$$

Similar to the estimation of risk attitudes, we included the household characteristics for the robustness check of the estimation.

3.5.Sample selection

Jambi Province is located on the east coast of central Sumatra.A multi-stage sampling method was used to select the participants for this study. In the first stage, five regencies were selected purposively: Batanghari, Bungo, Muaro Jambi, Sarolangun, and Tebo. These five regencies constituted the largest parts of lowland farming areas in Jambi Province (Krishna *et al.,* 2017). In the second stage, we utilised a random sampling method to select the villages. Eight villages per regency were selected randomly, resulting in a total of 40 villages. The number of observations per village varied depending on the population of farmers. We obtained the list of all farmers from the village heads or leaders of farmer-groups. The participants per village were selected randomly and afterwards, in line with the objective of this study, we involve rubber farmers (N = 437 farmers) and farmers who cultivated rubber and oil palms, as so-called double-crop farmers (N = 199 farmers). The participants were the household heads, who are commonly the families' decision makers. We also interviewed the farmers for socio-demographic information of the farmers' household. Our field experiment in Jambi took place from October 2016 until January 2017.

4. DESCRIPTIVE STATISTICS AND RESULTS

4.1.Descriptive statistics

The descriptive statistics for several variables are portrayed in Table 3, differentiating between double- crop and rubber farmers. To test the differences between the two groups of farmers, we utilised two types of test: the Chi-square test and Mann-Whitney U test. The Chi-square test was applied for the variables with binary responses (1/0). The Mann-Whitney U test is utilised for the variables with continuous values.

The two groups of farmers have more male farmers than female, but the Chi-square test show that the percentage of male in the double-crop groups was higher. 17% of double crop farmers have a car and 6% of the households owned a truck, while only around 6% of rubber farmers have a car and almost none of them owned a truck. This indicated that the double crop farmers have cars or trucks more than rubber farmers. There are two types of land title in Jambi Province: (1) official land titles; (2) sporadic or informal land titles. The sporadic land title is recognised by the local government but cannot be used for formal transactions such as collateral (Krishna *et al.,* 2017). Our data show that the share of farmers holding official land titles is larger among the double-crop farmers. Finally, our dataset shows that double-crop farmers use more services from the banking institution (*e.g.,* microcredit and savings).

The farmers from both groups were in the early stage of middle age averaging 48 years old, but the Mann-Whitney U test told us that double-crop farmers were older. The Mann-Whitney U test which applied for the variables plantation age, plantation area and productive plantation area, are conducted to compare the rubber plantations owned by rubber farmers and the rubber plantations owned by double-crop farmers[8]. We found that rubber plantations owned by the double-crop farmers were older and larger in size. The productive plantation areas were also larger. A motorbike was the most common transportation vehicle in the rural area of Jambi. On average, the households in our sample had around two motorbikes, but double-crop farmers had more motorbike than rubber farmers.

Table 3. Descriptive Statistics [a]				
Variables (unit)	Variables' explanations	Mean (st. dev.) / share in %		p-value[b]
		Rubber farmers	Double-crop farmers	
(1)	(2)	(3)	(4)	(5)
Socio-demographic				
Age (years)	Age of smallholder	45.85 (10.21)	47.94 (10.31)	0.01**
Gender (1/0)	= 1, if male	95.88%	98.49%	0.09*
Plantation age[c] (years)	Age of plantations	18.07 (9.42)	Rubber 20.04 (9.31) Oil palm 7.56 (5.83)	0.01**
Plantation area[c] (hectare)	Size of plantation areas	2.98 (3.23)	Rubber 3.89 (4.94) Oil palm 2.83 (3.15)	0.01**
Productive area (hectare)[c]	Size of productive plantation areas	2.39 (2.49)	Rubber 3.19 (3.92) Oil-palm 1.93 (3.19)	0.01**
Assets				
Car (1/0)	= 1, if own cars	6.17%	17.09%	0.00***
Land title (1/0)	= 1, if official title	26.32%	37.19%	0.01**
Motorbike	Number of motorbikes	1.86 (0.82)	2.19 (1.03)	0.00***
Truck (1/0)	= 1, if own trucks	0.46%	3.52%	0.00***
Access to banking				
Loan (1/0)	= 1, if own loan	44.62%	56.78%	0.00***
Saving (1/0)	= 1, if own saving	23.34%	43.72%	0.00***
Notes: [a]N = 636 (437 rubber farmers, 199 double-crop farmers); [b]Significance levels: *** at 1% level, ** at 5% level, * at 10% level; [c]On the variable plantation age, plantation area and productive plantation area; the tests are carried out to compare the rubber plantations owned by rubber farmers and rubber plantations owned by double-crop farmers.				

4.2.Results

To test the hypotheses, we estimated the risk attitudes and discount rate based on equations (5) and (9) using two models, without considering the household characteristics. Model 1 performed a joint-estimation of the risk aversion coefficient θ and discount rate δ for both groups of farmers separately. Thus at first, we jointly-estimated the risk attitudes and discount rate of rubber farmers. Secondly, we estimated the risk attitudes and discount rate of double-crop farmers. As the θ and δ of both groups were estimated separately in model 1, we presented the results in separate columns in Table 4. Model 2 provided the joint-estimations using the observations of both groups together. To do so, we created a dummy variable "double-crop farmer," where the value 1 indicated double-crop farmers and 0 for other. The results of the estimation using the model 1 and model 2 are presented in Table 4.

Table 4. Results of the joint-estimations of risk attitude and discount rate of farmers[a]			
Parameters	Model 1 (joint estimation of both group separately)		Model 2 (joint estimation of both group together)
	Coefficients	Coefficients	Coefficients
Panel A. Risk aversion coefficient (θ)			
Rubber farmers	0.03	-	0.04
Double-crop farmers	-	0.21***	0.13**
Panel B. Discount rate (δ)[b]			
Rubber farmers	2.97***	-	2.74***
Double-crop farmers	-	2.06***	2.56***
Notes: [a]N = 636 (437 rubber farmers, 199 double-crop farmers); [b]Significance levels: *** at 1% level, ** at 5% level, * at 10% level; [c]On the variable plantation age, plantation area and productive plantation area; the tests are carried out to compare the rubber plantations owned by rubber farmers and rubber plantations owned by double-crop farmers.			

Panel A of Table 4 showed that the estimation of the risk aversion coefficient is θ. There were three areas of estimated θ to define the risk aversion of the participants in the HL-task: (1) the value of θ is not statistically significantly different from zero, indicating risk-neutral individuals; (2) the value of θ is negative and statistically significantly different from zero, indicating risk-loving individuals; (3) the value of θ is positive and statistically significantly different from zero, indicating risk-averse individuals (Holt and Laury, 2002). Our results showed that the estimated θ of rubber farmers was positive but not statistically significantly different from zero. This implied that on average, rubber farmers are risk-neutral individuals. The estimations of θ for double-crop farmers were positive and statistically significantly different from zero at a significant level of 1% and 5% respectively. These results indicate that double-crop farmers were on average risk-averse individuals. These results were quite robust and the two models provide qualitatively the same findings. The observed rubber farmers are on average risk-neutral is consistent with the study by Clough *et al.* (2016). The risk attitudes of the double-crop farmers corresponded with farmers in other countries, as they are on average risk-averse (Liebenehm and Waibel, 2014; Tanaka *et al.,* 2010). The first hypothesis was formulated as "*more risk-averse farmers cultivate oil palms besides rubber* " The estimation results show that double-crop farmers were more risk-averse and therefore, we can conclude that risk-averse farmers realize a more diversified portfolio and support hypothesis 1.

Panel B presented the estimated discount rate δ. We used the estimated δ of rubber farmers in model 1 as an example to interpret the meaning of the estimated δ. The δ is 2.97, indicating that the discount rate was 297%, on average. Using model 2, the estimated discount rate of the rubber farmers was 274%. Furthermore, the estimated discount rate of double-crop farmers in the model 1 was 206% and using the model 2 was 256%. The results from the two models show that the discount rate of the double-crop farmers is lower than the rubber farmers. To examine whether the discount rates from the two groups of farmers were statistically significantly different, we utilise a t-test. The results of the t-test on the two model show that the differences of the discount rate from the two groups of farmers are not statistically different (p-value = 0.16 for model 1; p-value = 0.78 for model 2). This result contradicted our expectation in hypothesis 2, which stated that "*farmers with higher discount rate cultivate oil palms besides rubber*" and hence, we cannot support hypothesis 2.

To avoid the overestimated discount rate, one can apply two methodical approaches. First, a small range of interest rates is in the CW-task should be applied, *i.e.,* not too high upper border of the interest rate. Thus, we used the range from 10% to 100% in the CW-task. Secondly, the discount rates and risk attitudes should be jointly estimated (Andersen *et al.*, 2008). For example, Andersen *et al.* (2008) and Sauter and Mußhoff (2018) proved significantly lower discount rate by utilising the joint estimation method. We encountered the extremely high discount rate for both groups of farmers even though we already applied the two methodical approaches. However, in the context of low-income countries, high discount rates are rather common (Holden *et al.,* 1998) and previous study also estimated a high discount rate, *i.e.,* 250% (Coble and Lusk., 2010).

In order to further examine the robustness of the findings, we estimate the risk attitudes and time preferences including the household characteristics as formulated in the equation (5) and (9). This estimation was similar to the model 2, besides here we include the household characteristics. The results of the estimation are presented in Table 5, where the dummy variable double-crop farmer was statistically at 1% level for the risk attitudes and not statistically significant for the discount rate. Under these circumstances, we can conclude that the results from model 1 and model 2 were maintained (cf. Table 5): (1) the risk attitudes of both groups of farmers were statistically significantly different, *i.e.,* the double-crop farmers are on average more risk-averse than; (2) the discount rates of both groups of farmers are not statistically significantly (p-value = 0.92). Furthermore, we found that age and having a loan had a statistically significant effect on farmers' risk attitudes at a 5% significance level. This implied that older farmers were more risk-averse than younger farmers and indicated that farmers who have loans were less risk-averse than farmers without loans. However, none of the variables statistically significantly affect farmers' time preferences.

Table 5. Results of the joint-estimations of risk attitude and discount rate with household characteristics[a]

Parameters	Coefficients (st. error) for the estimation of θ	Coefficients (st. error) for the estimation of δ
Double-crop farmers (1/0)	0.18 (0.07)***	1.01 (0.59)
Age (years)	0.01 (0.01)**	-0.02 (0.03)
Car (1/0)	0.00 (0.10)	0.44 (1.25)
Gender (1/0)	-0.13 (-0.15)	1.26 (0.95)
Land title (1/0)	-0.09 (-0.06)	-0.08 (0.66)
Loan (1/0)	-0.13 (-0.06)*	0.83 (0.72)
Motorbike	0.02 (0.03)	0.41 (0.36)
Plantation age (years)	0.00 (0.00)	0.03 (0.04)
Plantation area (hectare)	0.00 (0.01)	-0.02 (0.08)
Productive plantation (hectare)	-0.01 (0.02)	0.01 (0.09)
Saving (1/0)	0.06 (0.06)	-0.95 (0.62)
Truck (1/0)	-0.04 (0.14)	-1.38 (2.22)

Notes: [a]Observations for rubber farmers = 8,740 (clusters = 437) and double-crop farmers = 3,980 (clusters = 199); the significance level indicates the difference between estimated θ and zero at 1% level (***), 5% level (**) or 10% level (*).

4.3.Discussion

Annual yields of rubber fluctuate due to the interferences from rainfall and low humidity (Miyamoto, 2006; Rist *et al.,* 2010, while the production of oil palm fruits was relatively more stable in a year round (Feintrenie *et al.,* 2010). However, the price volatility of oil palm fruits in farm-gate was higher than the price volatility of rubber (cf. Figure 1) and oil palms yields are more perishable because the fruits should be milled within two days after harvest, resulting to high dependency to the mills/factories (Gatto *et al.,* 2015). Under these circumstances, we expected that more risk-averse farmers would undertake crop diversification, *i.e.,* cultivate oil palm trees besides rubber. The benefits of crop diversification in stabilising farmers income has been discussed in the literature (*e.g.,* Heady, 1952). Dercon (1996) also stated that in a country where agricultural insurance is not well-established, crop diversification is an effective alternative to alleviate income uncertainties. Moreover, the positive effects of diversification were investigated in several empirical studies (*e.g.,* Bezabih and Sarr, 2012; Chavas and Di Falco, 2012). These studies provided evidence that crop diversifications have a purpose for smoothing farmers' income during the "bad season" for one particular crop. Nevertheless, this positive effect of diversification is only meaningful if the coefficient correlation between the expected return of two crops was less than one. The coefficient correlation between the expected return from oil palm and rubber plantation per land unit was 0.31, suggesting that farmers should diversify to maximize the expected returns while minimising the variances (Markowitz, 1952).

Our results encountered the previous studies (*e.g.,* Bezabih and Sarr., 2012; Chavas and Di Falco., 2012) when we found that more risk-averse farmers undertook the crop diversification, *i.e.,* cultivating rubber and oil palm together. Previous studies in Indonesia investigating the adoption of oil palm cultivation by smallholder farmers (Euler *et al*., 2017; Feintrenie *et al.,* 2010) also mentioned that the adopters of oil palms favour the yield from oil palm cultivation when they cannot rely on income from rubber during the rainy season. However, the estimated discount rates are not statistically significantly different among the two groups of farmers. This indicated that the rubber farmers are not differed with double-crop farmers in terms of discount rate.

The result of this study will be relevant information for the government to implement future policy measures, for example, encouraging or discouraging the adoption of oil palm cultivation by farmers. If the government decided to discourage the expansion of oil palm cultivation due to environmental concern regarding rainforest deforestation (Brandi *et al.,* 2015), then the government should implement agricultural insurance reducing income rubber due to weather (Barnett and Mahul, 2007; De Nicola. 2015). Conversely, when oil palm cultivation is encouraged, then the policies which maintain price stability and improve access to market should be implemented. Even though we did not discover the difference of discount rate between two groups of farmers, we revealed that the discount rates of the farmers are high. The policymakers and the farmers themselves have to put consideration about these high discount rates. High discount rates often hinder farmers' adoption on new technology and resulting on slow growth and poverty (Stevenson *et al.,* 2014).

5. CONCLUSION

Farmers constitute a large share of the populations of villages in many developing countries and hence, enhancing agriculture has been utilised to accelerate the development of rural areas (Ashley and Maxwell, 2001). One policy measure to reduce the uncertainties of income caused by various sources of risk in farming is crop diversification. For a farmers' decision making related to the diversification, risk and time preferences are important. Thus, the understanding of farmers' risk attitudes and time preferences are important for a meaningful policy analysis/recommendation regarding agriculture. However, the investigation of crop diversification is limited to seasonal/annual crops and provides ambiguous conclusions. This study investigates the risk attitudes and time preferences involving two groups of farmers in Indonesia cultivating perennial crops. To conduct the investigation, we involved rubber farmers and double-crop farmers, *i.e.,* farmers who cultivate rubber and oil palms. We expected that the latter group is more risk-averse and has higher discount rate. Our investigation generates two main findings: (1) the rubber farmers are risk neutral and double-crop farmers are risk-averse, on average; (2) the time preferences of both groups are not statistically significantly different.

Therefore, our study provided empirical proof that experimentally measured risk attitudes can explain a farmers' decision to diversify perennial crops, *i.e.,* cultivate rubber and oil palms. This finding enriches the existing literature which investigates crop diversification of seasonal/annual crops with perennial crops, as we focused on cultivation of two perennial crops. We found that double-crop farmers are on average risk-averse, where they undertake crop diversification to stabilise income. Under these circumstances, the policymaker should establish supporting systems to help farmers managing two or more perennial crops. For instance, improved access to microfinance for capital lending, seedling, fertilizer and irrigation. Furthermore, we found that both groups of farmers have a high discount rate. A high discount rate promoted hesitance towards making a long-term investment because the individuals had to put a low value on future rewards trapping farmers into poverty. The Indonesian government could overcome this problem by increasing education and knowledge programs to help mitigating the high discount rate (Bauer and Chytilová., 2010).

Finally, it would also be of interest to explicitly investigate the motivation of the decision to diversify crop by using economic experiments and normative model calculation (*e.g.,* using the analogy between investments in different stocks and decision to diversify crops). Furthermore, future research can also extend the sample coverage by involving rubber farmers who switched completely to oil palms. In this way, the comparison of risk attitudes and time preferences of farmers undertaking crop-diversification and farmers switching crop could be carried out.

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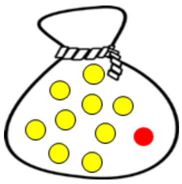
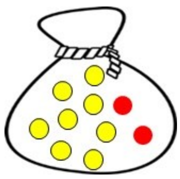
APPENDIX

Table A1. Holt and Laury task*

	Bag A	Option (A or B)	Bag B
1	 1 red ball, 9 yellow balls	……	 1 green ball, 9 blue balls
2	 2 red balls, 8 yellow balls	……	 2 green ball, 8 blue balls

*due to page limitation, we only present the series 1 and 2 here.

NOTES

[1] This study investigates farmers' decision to diversify between one annual crops included (rape, wheat or barley) and one type of perennial crops (switchgrass or miscanthus).
[2] The price of oil palm fruits at the farm-gate is determined by a weekly meeting of the Ministry of Agriculture at the province level, private companies and farmer groups (Hidayat *et al.,* 2015). We obtained the price of oil palm fruits from the weekly meeting transcript. The price of oil palm fruits differs depending on the trees' age and thus, we used the average price of oil palm fruits from different ages of trees. The rubber price is assigned daily, depending on the world price (Feintrenie and Levang, 2009; Marimin *et al.,* 2014). We obtained the daily price of rubber from GAPKINDO. To make the price of both crops comparable, we used the Thursday price of rubber because the price of oil palm fruits is determined every Thursday.
[3] To obtain the information about the productivities, we refer to annual report from the Ministry of Agriculture for the year 2012 to 2015.
[4] 1$ ≈ 13,440 IDR.
[5] Daily wage of labor working in the rural area of Jambi Province was on average 50,000 IDR.
[6] We avoided giving cash incentives because it might be associated with bribing. Moreover, in some villages, the data collection also occurred nearly simultaneously with local leader elections where it could be crucial that the participants would think that we bought votes for a particular politician.
[7] The shopping voucher contained the following information including: the value of the shopping voucher, the shop where the shopping voucher was valid and the date when the shopping voucher could be used. In this way, the participants cannot exchange the shopping vouchers before the determined date.
[8] The double-crop smallholders own oil palm plantations, but the rubber smallholders do not own oil palm plantations. Thus, it is not necessary to conduct the Mann Mann-Whitney U test for variables plantation age, area and productive area of oil palm plantations.