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ARE RISK ATTITUDES AND TIME PREFERENCES CRUCIAL FACTORS FOR CROP DIVERSIFICATION BY SMALLHOLDER FARMERS?

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Abstract: This study examines whether the decision of crop diversification for perennial crops is based on risk attitudes and time preferences. We conducted incentivised field experiments with farmers only cultivating rubber and those cultivating rubber and oil palm. We utilised Holt and Laury task and Coller and William task. We found that farmers who cultivate two crops are more risk-averse, indicating that they see crop diversification as a safer option for their farms. However, the discount rates of the two groups are not significantly different. These results provide relevant information for policymakers who intend to either encourage or discourage oil palm cultivation. © 2020 The Authors. Journal of International Development published by John Wiley & Sons Ltd

Keywords: crop diversification; oil palms; perennial crops; risk attitudes; rubber; time preference
JEL Classification: D13; Q12; Q15

1 INTRODUCTION

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

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Crop diversification is the practice of cultivating two or more crops at the same time in order to reduce income risks by creating more than one source of income. Crop diversification can also provide external benefits such as (i) supporting non-chemical pest management (Theunissen, 1994) and (ii) promoting biodiversity such as in the bird population (Henderson, Ravenscroft, Smith, & Holloway, 2009). Based on the existing literature, the relationship/dependency between risk attitudes and crop diversification is 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 that more risk-averse farmers are less likely to diversify crops among farmers from the USA. 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, for example, Bezabih and Sarr (2012), Chavas and Di Falco (2012), Dercon (1996) and 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. For example, compared with seasonal/annual crops, perennial crops are more susceptible to diseases because crop rotation and fallow periods cannot be carried out to prevent the spread of disease (Cox, Garrett, & Bockus, 2005).

Furthermore, time preferences come into consideration when farmers deal with perennial crops, due to the long gap between planting and harvesting (Sauter & 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, (i) cultivating perennial crops associates to the possibility of suffering from future climate change (Lobell, Field, Cahill, & Bonfils, 2006), and (ii) 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, existing studies that examine crop diversification between one annual and one perennial crop towards risk are those of Bocqueho and Jacquet (2010) and Ouattara, Kouassi, Egbendéwé, and Akinkugbe (2019).[1] Both studies found that risk aversion hinders diversification on perennial crop but did not analyse the effect of time preferences. Nevertheless, the relationship/dependency between farmers' time preferences and diversification of two perennial crops 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, more specifically in Jambi Province where rubber has been the most important cash crop since the beginning of the 19th century (Casson & Obidzinski, 2002). Rubber has been planted throughout generations and has become a cultural cash crop (Feintrenie

[1]Bocqueho and Jacquet (2010) investigate farmers' decision to diversify between one type of annual crops (rape, wheat or barley) and one type of perennial crops (switchgrass or miscanthus). Ouattara et al. (2019) investigate farmers' decision to diversify between one annual crop (corn) and one perennial crop (cashew nut).

& Levang, 2009; Gatto, Wollni, & Qaim, 2015). In 1990, the government introduced oil palms, which opened an opportunity for farmers to cultivate them besides rubber. Since then, oil palm plantations started to be established by smallholder farmers (Gatto, Wollni, Asnawi, & Qaim, 2017).

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, that is, 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 & Sarr, 2012; Chavas & Di Falco, 2012; Dercon, 1996). Besides, involving Indonesian farmers, 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, and hence, 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 follows: Section 2 presents the derivation of the hypotheses. The Holt and Laury task (HL task; Holt & Laury, 2002) and Coller and Williams task (CW task; Coller & Williams, 1999), 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 perennial cash crop in Sumatra until the period when the transmigration programmes promoted more intensive farmland use and introduced oil palms (Feintrenie & Levang, 2009; Gatto et al., 2015). In the beginning, oil palm plantations were established by large-scale plantations owned by the government and private companies. Following them, smallholder farmers also cultivated oil palm with or without direct supports from the government (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 one of the production areas of palm oil. Even though a greater proportion of farmers cultivate rubber, adoptions of oil palm cultivation keep happening (Euler et al., 2017; Gatto et al., 2015). To compare the risk attitudes and time preferences of farmers who cultivated rubber and farmers who cultivated both rubber and oil palm, we formulated two hypotheses 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 & Hardaker, 2001); for example, drought and other cases of extreme weather can substantially diminish farmers' incomes (Turvey & 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, Chong, & Levang, 2010). Second, low humidity causes rubber trees to produce less latex (Miyamoto, 2006). In contrast, oil palm trees are less affected by the weather, and hence, the harvest can be throughout the year (Rist, Feintrenie, & Levang, 2010).

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's (2010) calculation for price volatility of agricultural products, the estimated price volatility of rubber was 15.76 per cent and the price volatility of oil palm fruits in farm gate was 21.28 per cent.

From the two aforementioned risk factors, we can therefore state that cultivation of rubber and oil palm trees faces different risk levels in different areas; that is, rubber is riskier in terms of 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 referred to the portfolio concept (Markowitz, 1952), which explains that every investment has expected returns and variances. According to the portfolio concept, the variance of investment could be reduced by diversifying investments. This must consider that each of the different investments has its own variance. Indeed, the diversification cannot eliminate all potential variances from the investments, but it provides maximum expected returns with minimum variances (Markowitz, 1952). Thus, the effect of portfolio occurs if the correlation coefficients between the expected returns of both investments are less than one and ideally negative. The portfolio effect occurs if farmers mix different activities, that is, cultivate more than one crop, as so-called crop diversification (Dercon, 1996; Heady, 1952; Pellegrini & Tasciotti, 2014). Literature has proven the benefits of crop diversifications such as Heady (1952).

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 coefficients of the expected returns from both crops. The expected returns of both crops are not perfectly correlated (correlation coefficient is 0.31), suggesting that cultivating both rubber and oil palm can allow the farmers to obtain the benefit of crop diversification. In this regards, risk-averse farmers would have an incentive to cultivate rubber and oil palms together. Accordingly, we can formulate the first hypothesis as follows.

H1 *More risk-averse farmers cultivate oil palms besides rubber.*

[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, Glasbergen, & Offermans, 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 & Levang, 2009; Marimin, Putra, & Wiguna, 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.

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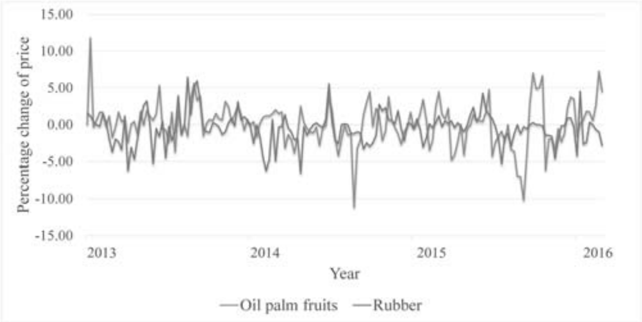

Figure 1. Percentage change of weekly price for oil palm fruits and rubber at the farm gate (*N* = 165; the source for oil palm fruits price was from weekly meeting of the Ministry of Agriculture at the province level; the source for rubber price was from GAPKINDO—the Rubber Association of Indonesia). [Colour figure can be viewed at wileyonlinelibrary.com]

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 with rubber. The first harvest of oil palm trees starts in the fourth year after planting, and oil palm trees can be harvested up to the age of 25 years (Corley & Tinker, 2016). While to yield the first harvest of rubber, farmers must wait for 7 years, they can obtain yields longer, that is, 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 & Williams, 1999), and farmers are characterised 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 follows.

H2 *Farmers with higher discount rate cultivate oil palms besides rubber.*

3 METHODOLOGY

The study involved 636 Indonesian smallholder farmers. We included two groups of farmers: (i) farmers who cultivated only rubber and (ii) farmers who cultivated rubber and oil palm trees. The farmers diversify rubber plantation with oil palm, where oil palm trees were planted after rubber and the average size of oil palm farms was smaller than rubber farms (Euler et al., 2017; Feintrenie et al., 2010). We estimated the risk attitudes and time preferences experimentally. An HL task was used to observe the risk attitudes, and a CW task was conducted to determine the time preferences by estimating individual discount rates. The HL task and CW task have been used in several studies involving rural people and farmers in particular (Holden & Quiggin, 2017; Ihli, Chiputwa, & Musshoff, 2016; Tanaka, Camerer, & Nguyen, 2010). Both tasks were incentivised, that is, payouts were given for each of task, to encourage sensible and realistic decision making by the participants during the experiments (Hertwig & Ortmann, 2001). We applied the joint estimation method by Andersen, Harrison, Lau and Rutström (2008) where risk attitudes are considered when estimating the discount rate.

3.1 Research Area and Sample Selection

The research was conducted in Jambi Province, which is located on the east coast of central Sumatra, Indonesia. Jambi covers the area of about 5 million hectares, which consists of highlands that have largely been conserved and lowland rainforest that has recently been converted to agricultural lands (Clough et al., 2016). By 2013, around 50 per cent of Jambi's lands were agricultural land, and more than half of the population worked in the agricultural sector (Clough et al., 2016; Drescher et al., 2016). For many decades, rubber trees were the most important cash crop in Jambi and were planted by several generations (Casson & Obidzinski, 2002). The earliest cultivation method of rubber in Jambi is called 'rubber agroforest', which started around the year 1900, in which rubber was cultivated together with other cash and non-cash crops imitating the rich diversity of plants in forest areas (Rembold, Mangopo, Tjitrosoedirdjo, & Kreft, 2017). Rubber seedlings were planted among upland rice, vegetables and fruits, where the agroforest system enabled farmers to obtain income from these quick-developing plants (Feintrenie & Levang, 2009). These plants provided a safety net of income before the farmers could obtain yields from the rubber, which come in the seventh year. By the end of the 20th century, gradually, rubber monocultures were established (Feintrenie et al., 2010). In Jambi, oil palm tree was introduced together with the transmigration programmes started in 1990s and was a promising alternative of income source (Feintrenie et al., 2010; Gatto et al., 2015).

Our research took place in the lowland areas where rubber and oil palm are largely cultivated including Batanghari, Bungo, Muaro Jambi, Sarolangun and Tebo regency. These five regencies constituted the largest parts of lowland farming areas in Jambi Province (Krishna, Kubitza, Pascual, & Qaim, 2017). Furthermore, eight villages per regency were selected randomly and five additional villages were added purposively to support the ongoing research project (see Clough et al., 2016; Krishna et al., 2017; Kubitza, Krishna, Alamsyah, & Qaim, 2018), resulting in a total of 45 villages. In Figure 2, we present the map of Jambi Province and the spatial distribution of the research 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. We included 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 obtained socio-economic and demographic information of the households. Our field experiment in Jambi took place from October 2016 until January 2017.

3.2 Holt and Laury Task

To elicit the risk attitudes, we carried out an incentivised HL task using the multiple price list, where the participants were confronted with a series of 10 paired lotteries. Within the

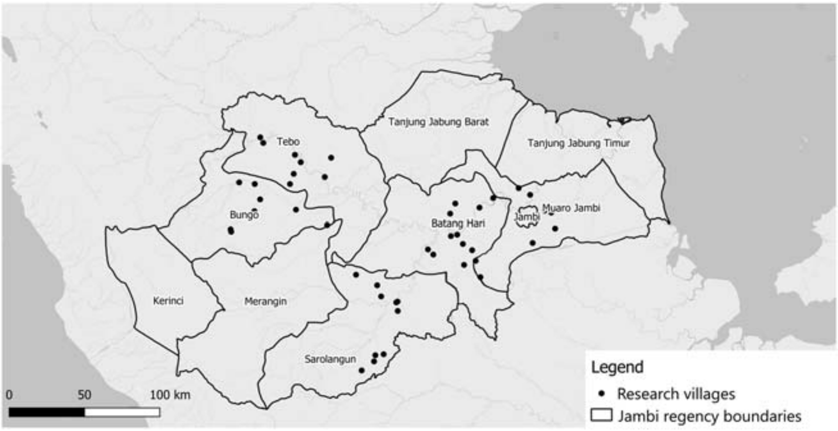

Figure 2. Map of Jambi Province indicating the research villages (cartography = Christoph Kubitza, Department of Agricultural Economic and Rural Development, Georg-August-Universität Göttingen)

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 4000 Indonesian Rupiah (IDR) and 3200 IDR, and the payoffs in option *B* are 7600 IDR and 200 IDR.[4] The difference between the high and low payoff in option *A* is less compared with 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 & 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 visualised following Ihli et al. (2016), where images of balls with four different colours inside of two closed bags to depict the payoffs were used. Red and yellow represented the high and low payoffs in option *A*, while green and blue visualised high and low payoffs in option *B*. In each row, the proportions of coloured balls changed according to the probabilities. For example, in row 1, bag A contained one red ball and nine yellow balls, while bag B contained one green ball and nine blue balls. In row 2, bag A contained two red and eight yellow balls, while bag B contained two green and eight blue balls, and so on until row 10 (example of how we presented the multiple price list to the participants is in Table A1 of the Supporting Information).

One might wonder whether the usage of coloured images in the HL task has potential problem of colour bias. The colour bias occurs if there is an association between colour preferences and aspects of socio-economic and demographic background such as gender (e.g. Ellis & Ficek, 2001; Hurlbert & Ling, 2007). Nevertheless, the purpose of using the images of coloured balls was to help farmers to better understand the HL task as argued by Ihli et al. (2016). In this way, the researcher can avoid the problem of misunderstanding

[4]$1 ≈ 13 440 IDR.

Table 1. Multiple price list of the Holt and Laury task of rubber and double-crop farmers

Row	Option *A*	Choice	Option *B*	Expected payoff difference
1	10% of 4000, 90% of 3200	...	10% of 7600, 90% of 200	2340
2	20% of 4000, 80% of 3200	...	20% of 7600, 80% of 200	1680
3	30% of 4000, 70% of 3200	...	30% of 7600, 70% of 200	1020
4	40% of 4000, 60% of 3200	...	40% of 7600, 60% of 200	360
5	50% of 4000, 50% of 3200	...	50% of 7600, 50% of 200	−300
6	60% of 4000, 40% of 3200	...	60% of 7600, 40% of 200	−960
7	70% of 4000, 30% of 3200	...	70% of 7600, 30% of 200	−1620
8	80% of 4000, 20% of 3200	...	80% of 7600, 20% of 200	−2280
9	90% of 4000, 10% of 3200	...	90% of 7600, 10% of 200	2940
10	100% of 4000, 0% of 3200	...	100% of 7600, 0% of 200	−3600

The amount of payoff is in IDR.

written tasks for illiterate participants or participants with a very low level of education, which are common cases in developing countries (Nielsen, Keil, & Zeller, 2013). Utilising the coloured images to increase farmers' understanding is important because the failure to understand the task leads to inconsistency and could potentially lower the reliability of the risk attitude measurement (Ihli et al., 2016). Moreover, during the experiment, we also explained that one colour depicts certain amount of money; the red ball was 4000 IDR, yellow was 3200 IDR, green was 7600 IDR and blue was 200 IDR. Providing the information of the nominal values possibly helped avoid favouritism of a particular colour.

To check for the presence of the colour bias in our sample, we analyse the strength of relationships between farmers' background and selections of the two options in the HL task, which depicted four colours: option *A* (red and yellow) and option *B* (blue and green). To do so, we calculated the correlation coefficients (ρ) between the socio-economic and demographic variables and the selection of the two options in the HL task. The results of the calculation are presented in Table A2 of the Supporting Information. As we can observe, the value of the measured ρ are very close to zero with positive or negative signs, indicating weak relationships.[5] Therefore, in this circumstance, we can be confident that the selection of option *A* or *B* in the HL task was based on the risk preferences instead of preferences towards colours. Finally, even if slight colour bias is present, we can expect that the colour bias would apply for all participants from both groups of farmers: double-crop and rubber farmers. Because the colour bias should be the same for both groups as presented in Table A2 of the Supporting Information, and we compare them, then, the case of colour bias is not critical for group comparison.

[5]We conducted *t*-test to examine whether the ρ are statistically significantly different from zero. For the rubber farmers, the variables age and loan are significant at the 5 per cent level. For the double-crop farmers, the variables car ownership and plantation area are significant at the 5 per cent level. However, in a large sample size such as in our dataset, a small value for ρ can be significantly different from zero at any level, and hence, the significance has little practical importance for interpretations for the *t*-test (Taylor, 1990). Accordingly, Taylor (1990) suggested the use of the following categories of ρ, where $\rho \leq 0.35$ indicates weak relationship, $0.35 \leq \rho \leq 0.67$ indicates a moderate relationship, $0.68 \leq \rho \leq 0.90$ indicates a strong relationship and >0.9 indicates a very strong relationship. Otherwise, a further step could be to calculate the coefficient of determination (ρ^2) by squaring the ρ (Taylor, 1990). The ρ^2 indicates the percentage of farmers' choice for option *A* or *B* in the HL task that can be explained by the socio-economic and demographic variables. For example, the ρ of the variable age for rubber farmers is 0.12, and hence, the ρ^2 is 0.01; this means that only 1 per cent of the total variation in the choice of option *A* or *B* can be explained by age, even though the variable is statistically significant.

Table 2. Payoff matrix of the Coller and Williams task of rubber and double-crop farmers

Row	Option *I* (in 7 days)	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

The amount of payoff is in IDR.

3.3 Coller and Williams 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 (7 days) for which the payoff amount is fixed at 50 000 IDR.[6] We applied front delay in option *I* for 1 week to reduce participants' temptation to obtain a 'today' gain; hence, a present bias was avoided (Andersen et al., 2008). As receiving the payouts in the future comes with the uncertainty of reliability, hence, the front delay for both options hold the participants' transaction cost constant (Laury, McInnes, & Swarthout, 2012). Option *II* was a payoff in 3 months (90 days). The values of payoffs in option *II* increase along the 10 rows of the matrix payoff in Table 2, depending on the amount of the annual interest rates. We set the 90-day delay for option *II* according to two reasons: (i) 90-day delay was previously used in the literature (e.g. Hermann & Musshoff, 2016; Laury et al., 2012), and (ii) too long waiting period for 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.[7] 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 per cent to 100 per cent. 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.

3.4 Monetary Incentives

There were two steps to determine the payouts in the HL task: (i) participants took one out of 10 numbered coins from a closed bag. The chosen coin showed one randomly selected

[6]Daily wage of labour working in the rural area of Jambi Province was on average 50 000 IDR.
[7]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 politician.

row out of the 10 rows of the HL task, for which the incentive was given. (ii) 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 4000 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 10 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 90th day after the experiments.[8]

3.5 Joint Estimation Method

Following the 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 (Holt & Laury, 2002):

$$U(X) = \frac{(X)^{1-\theta}}{1 - \theta}, \tag{1}$$

where U is the utility, X are the payoffs in the HL task and θ is the risk aversion coefficient.[9] 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 options A and B of the HL task can be formulated as (Andersen et al., 2008)

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

and

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

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 & Laury, 2002):

[8]The shopping voucher contained the following information: 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.
[9]Previous literature includes background consumption (ω) to define the utility (e.g. Sauter & Mußhoff, 2018). We assumed ω is equal to zero as in Andersen et al. (2008); therefore, we do not consider ω in Equation (1) and in further equations.

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

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)

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

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 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+τ = 90 days. Thus, τ is the time between the early and later payoffs, that is, 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}, and then the probability of a smallholder to choose 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

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

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

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-squared test and Mann–Whitney *U*-test. The chi-squared test was applied for the variables with binary responses (1/0). The Mann–Whitney *U*-test was utilised for the variables with continuous values.

The two groups of farmers have more male farmers than female farmers, but the chi-squared test showed that the percentage of male farmers in the double-crop groups was significantly higher. Seventeen per cent of double-crop farmers had a car and 6 per cent of the households owned a truck, while only around 6 per cent 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: (i) official land titles and (ii) 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 showed that double-crop farmers were significantly older. The Mann–Whitney *U*-tests, which applied for some variables including plantation

Table 3. Descriptive statistics of rubber and double-crop farmers

Variables (units)	Variables' explanations	Mean (SD)/share in % Rubber farmers	Double-crop farmers	*p* values
Age (years)	Age of farmers	45.85 (10.21)	47.94 (10.31)	0.01**
Car (1/0)	= 1, if own cars	6.17%	17.09%	0.00***
Gender (1/0)	= 1, if male	95.88%	98.49%	0.09*
Land title (1/0)	= 1, if official title	26.32%	37.19%	0.01**
Loan (1/0)	= 1, if own loan	44.62%	56.78%	0.00***
Motorbike	Number of motorbikes	1.86 (0.82)	2.19 (1.03)	0.00***
Plantation age[a] (years)	Age of plantations	18.07 (9.42)	Rubber 20.04 (9.31) Oil palm 7.56 (5.83)	0.01**
Plantation area[a] (ha)	Size of plantation areas	2.98 (3.23)	Rubber 3.89 (4.94) Oil palm 2.83 (3.15)	0.01**
Productive area[a] (ha)	Size of productive plantation areas	2.39 (2.49)	Rubber 3.19 (3.92) Oil palm 1.93 (3.19)	0.01**
Saving (1/0)	= 1, if own saving	23.34%	43.72%	0.00***
Truck (1/0)	= 1, if own trucks	0.46%	3.52%	0.00***

$N = 636$ (437 rubber farmers and 199 double-crop farmers).
[a]On the variables plantation age, plantation area and productive plantation area, the tests are carried out to compare the rubber plantations owned by rubber farmers with the rubber plantations owned by double-crop farmers.
***Significant at 1 per cent level.
**Significant at 5 per cent level.
*Significant at 10 per cent level.

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.[10] 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.

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 an estimation of the risk aversion coefficient θ and discount rate δ for both groups of farmers separately. Thus, at first, we estimated the risk attitudes and discount rate of rubber farmers simultaneously. Second, we estimated the risk attitudes and discount rate of double-crop farmers. As 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 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 models 1 and 2 are presented in Table 4.Panel A of Table 4 showed the estimation of the risk aversion coefficient (θ). There were three areas of estimated θ to define the risk aversion of the participants in the HL task: (i) the value of θ is not statistically significantly different from zero, indicating risk-neutral individuals; (ii) the value of θ is negative and statistically significantly different from zero, indicating risk-loving individuals; and (iii) the value of θ is positive and statistically significantly different from zero, indicating risk-averse individuals (Holt & 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 per cent and 5 per cent, 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 finding that 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 & 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 realise 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 per cent, on average. Using model 2, the

[10]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–Whitney *U*-test for variables plantation age, area and productive area of oil palm plantations.

Table 4. Risk aversion coefficients and discount rates of rubber and double-crop farmers

	Model 1		Model 2
Parameters	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)			
Rubber farmers	2.97***	—	2.74***
Double-crop farmers	—	2.06***	2.56***

N for rubber farmers = 8740 (number of clusters = 437) and *N* for double-crop farmers = 3980 (number of clusters = 199). The significance level indicates the difference between the values of θ and zero.
***Significant at 1 per cent level.
**Significant at 5 per cent level.
*Significant at 10 per cent level.

estimated discount rate of the rubber farmers was 274 per cent. Furthermore, the estimated discount rate of double-crop farmers in model 1 was 206 per cent, and 256 per cent using model 2. 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 models 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, that is, not too high upper border of the interest rate. Thus, we used the range from 10 per cent to 100 per cent in the CW task. Second, 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, Bekele, & Wik, 1998) and previous study also estimated a high discount rate, that is, 250 per cent (Coble & 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 Equations (5) and (9). This estimation was similar to model 2; besides, we include the household characteristics here. The results of the estimation are presented in Table 5, where the dummy variable double-crop farmer was statistically significant at 1 per cent 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): (i) the risk attitudes of both groups of farmers were statistically significantly different; that is, the double-crop farmers are on average more risk-averse than the rubber farmers, and (ii) the discount rates of both groups of farmers are not statistically significant (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 per cent significance

Table 5. Model estimates of risk attitude and time preferences with farmers' socio-economic and demographic variables

Variables (units)	Coefficients (SE) for the estimation of θ	Coefficients (SE) for the estimation of δ
Double-crop farmer (1 = double-crop)	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 (ha)	0.00 (0.01)	−0.02 (0.08)
Productive plantation (ha)	−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)

N for rubber farmers = 8740 (number of clusters = 437) and *N* for double-crop farmers = 3980 (number of clusters = 199). The significance level indicates the difference between the values of θ and zero.
***Significant at 1 per cent level.
**Significant at 5 per cent level.
*Significant at 10 per cent level.

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.

4.3 Discussion

Rubber has been cultivated for a long time and is one of the most important perennial crops in Jambi Province (Casson & Obidzinski, 2002). The land use has changed after the government introduced oil palm cultivation in this area in response to high demand for oil palm (Feintrenie et al., 2010). Even though a substantial amount of farmers have adopted oil palm, rubber tree remains the perennial crop, which is cultivated by most smallholder farmers (Feintrenie et al., 2010; Gatto et al., 2015). As we encountered in this study, farmers who diversify their perennial crops are more risk-averse than farmers who cultivate only one crop.

Annual yields of rubber fluctuate due to variable rainfall and low humidity (Miyamoto, 2006; Rist et al., 2010), while the production of oil palm fruits is more stable throughout the year (Feintrenie et al., 2010). However, the price volatility of oil palm fruits at the farm gate is higher than the price volatility of rubber (cf. Figure 1). Oil palms yields are more perishable than rubber because the fruits must be milled within 2 days of harvest, resulting in a high dependency on mills/factories (Gatto et al., 2015). Under these circumstances, we expected that more risk-averse farmers would undertake crop diversification, that is, cultivate oil palm trees alongside rubber. The benefits of crop diversification in stabilising farmers' income have 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 & Sarr, 2012; Chavas & Di Falco, 2012). These studies provided evidence that crop diversification has the purpose of smoothing farmers' income during the 'bad season' for one particular crop. Nevertheless, this positive effect of diversification is only meaningful if the correlation coefficient between the expected return of two crops was less than one. The correlation coefficient between the expected return from oil palm and rubber plantation per land unit was 0.31, suggesting that farmers should diversify to maximise the expected returns while minimising the variances (Markowitz, 1952).

Our results confirmed the previous studies (e.g. Bezabih & Sarr, 2012; Chavas & Di Falco, 2012), where more risk-averse farmers undertook the crop diversification, that is, 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 did not differ 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 fluctuation of rubber due to weather dependency (Barnett & Mahul, 2007; De Nicola, 2015). Conversely, when oil palm cultivation is encouraged, then the policies that 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, thereby resulting on slow growth and poverty (Stevenson, Serraj, & Cassman, 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 & 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 is 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, that is, 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:

(i) the rubber farmers are risk-neutral and double-crop farmers are risk-averse, on average, and (ii) 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, that is, cultivate rubber and oil palms. This finding enriches the existing literature that 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, policymakers should establish supporting systems to help farmers managing two or more perennial crops. For instance, the policymakers could improve access to microfinance for capital lending, seedling, fertiliser 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 programmes that help mitigate the high discount rate (Bauer & Chytilová, 2010).

With regard to the usage of images to visualise the HL task to help smallholder farmers to better understand the task, future research could modify the experiment by using randomisation of colours. This approach could be a useful strategy to prevent the possibility of colour bias during the experiment. Furthermore, it would also be of interest to explicitly investigate the motivation behind the decision to diversify crop production by conducting an in-depth interview with farmers. Finally, 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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Data Availability Statement

Research data are not shared.

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