

Oil palm cultivation, household welfare, and exposure to economic risk in the Indonesian small farm sector

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Abstract

The massive expansion of oil palm in tropical regions has substantial implications for socioeconomic development. Several studies show that smallholder farmers benefit economically from cultivating oil palm. However, most existing studies examine short-term impacts with cross-sectional data, which has two disadvantages. First, issues of endogeneity are difficult to address with cross-sectional data. Second, dynamic and risk effects cannot be analysed. We address both issues by using three waves of panel data from smallholder farmers in Indonesia and pseudo fixed effects panel estimators. We show that oil palm cultivation increases household living standards, measured in terms of annual consumption expenditures, by 13% on average. Moreover, we demonstrate that oil palm cultivation tends to reduce households' economic risk, measured in terms of potential decreases in living standard due to income variability. The risk-reduction effect is evident despite fluctuating international palm oil prices and consequences for oil palm revenues and profits. Oil palm requires less labour than alternative crops, thus freeing family labour for other economic activities. We find that oil palm farmers are more involved in off-farm activities, which helps to smooth income and consumption. Policy support may be required to address oil

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palm adoption constraints that some smallholders face. In addition, fostering the non-farm economy and improving household access to lucrative off-farm jobs are important for equitable rural development.

KEYWORDS

economic risk, household welfare, income diversification, Indonesia, oil palm

JEL CLASSIFICATION

C23; O12; O13; Q12

1 | INTRODUCTION

The rapid growth in global demand for vegetable oil over the past two decades has led to a massive expansion of oil palm in tropical regions, especially in Southeast Asia (Byerlee et al., 2017). In Indonesia, the world's largest palm oil producer, the area cultivated with oil palm more than tripled from 4 million hectares in 2000 to over 12 million hectares in 2018 (BPS, 2019). This major land-use change has various implications for sustainable development (Qaim et al., 2020). Apart from environmental problems, social issues and land conflicts between palm oil companies and local communities have been reported (Abood et al., 2015; Clough et al., 2016; Drescher et al., 2016; Santika et al., 2019; Sarwosri et al., 2020).

However, oil palm cultivation can also have positive socioeconomic effects for local communities. In Indonesia, around 45% of the oil palm land is cultivated by small family farms rather than large companies (BPS, 2019). Recent studies with village-level or regency-level data from Indonesia illustrate how oil palm production has contributed to rural economic development and poverty reduction (Edwards, 2019; Gatto et al., 2017; Kubitzka & Gehrke, 2018). There are also several studies that used household survey data to show that smallholder farmers benefit from oil palm cultivation in terms of higher incomes and living standards (Euler et al., 2017; Krishna, Euler, et al., 2017; Rist et al., 2010; Sibhatu, 2019).

One drawback of existing studies with household-level data is that most are based on cross-section surveys, meaning that potential issues of endogeneity in the impact evaluation are hard to address. A second drawback is that these studies mostly look at economic effects in only 1 year, whereas the effects of oil palm cultivation can vary over time, for instance through fluctuating world market prices or changing policies in importing regions (Taheripour et al., 2019). Fluctuating world market prices can lead to significant income variability and downside economic risk for smallholders (Cahyadi & Waibel, 2016; Cramb & Curry, 2012; Feintrenie et al., 2010; Klasen et al., 2016). Oil palm is a perennial crop that requires significant capital investment for plantation establishment. Hence, farmers' ability to switch to other crops when output prices decline is limited. In such situations, downside risk can potentially lead to considerable social hardship (Morduch, 1994). One recent study used two waves of survey data and confirmed that the economic effects of oil palm cultivation can vary significantly between different years (Kubitzka, Krishna, Alamsyah, et al., 2018). Downside risk was not analysed explicitly by Kubitzka, Krishna, Alamsyah, et al. (2018), nor were endogeneity issues due to unobserved heterogeneity properly addressed.

Here, we add to the literature in three particular ways. First, we provide more reliable estimates of the effects of oil palm cultivation on smallholder welfare by using three waves of panel data and regression models with pseudo fixed effects to control for time-invariant unobserved heterogeneity. Our panel data were collected in one of the hotspots of Indonesia's recent oil palm boom. Second, we analyse possible dynamic effects of oil palm cultivation on downside

economic risk. This is particularly interesting because our panel data cover a period of 6 years (2012–2018) during which substantial price fluctuations on international commodity markets were observed. Third, we analyse the main mechanisms underlying the effects of oil palm cultivation on smallholder welfare and economic risk. Direct effects could be due to differences in per-hectare profits between oil palm and alternative crops. In addition, indirect effects could occur through the reallocation of household resources, especially labour, to other economic activities. As is known from earlier studies, oil palm requires less labour per hectare than alternative crops (Chrisendo et al., 2020; Krishna, Euler, et al., 2017), meaning that family labour can be used to cultivate a larger land area and/or for off-farm employment. In particular, reallocating labour to off-farm employment can reduce economic risk, because off-farm earnings can offset fluctuating farm earnings.

2 | MATERIALS AND METHODS

2.1 | Study region and household survey

We use data from a farm household survey conducted in Jambi Province, Sumatra, as part of a large interdisciplinary research project (Drescher et al., 2016). Jambi is one of Indonesia's main palm oil producing provinces. The traditional cash crop in Jambi is rubber, which has been widely grown since the first half of the twentieth century, mostly by smallholder farmers. Rubber is still one of the dominant crops in the region, but the importance of oil palm has grown substantially during the last 30 years (Bou Dib et al., 2018; Qaim et al., 2020).

The expansion of oil palm in Jambi started in the 1980s as part of the Indonesian government's transmigration programmes. Families from densely populated Java and Bali were relocated to less populated islands such as Sumatra or Kalimantan, where they settled in newly established transmigrant villages and received small plots of land as well as technical and financial support for oil palm cultivation (Cramb & Curry, 2012). At first, these transmigrant smallholders cultivated oil palm under contract with public or private sector palm oil companies (Gatto et al., 2017). However, smallholders continued cultivating oil palm when the company contracts expired (Euler et al., 2016; Feintrenie et al., 2010). In addition, many of the previous rubber farmers from the indigenous population also gradually switched to oil palm due to its higher returns to labour (Bissonnette & De Koninck, 2017; Euler et al., 2017). In Jambi, up to 70% of the total oil palm area is cultivated by smallholder farmers, as compared to 45% for Indonesia as a whole (BPS, 2019).

For our survey in rural Jambi, we selected farm households in 2012 using a multi-stage sampling framework (Euler et al., 2017). Five lowland regencies, covering most of the oil palm area in Jambi, were purposively selected. In each regency, we randomly selected four districts, and in each district, we randomly selected two villages, resulting in a total of 40 villages (including indigenous and transmigrant villages). Five additional villages in the same regencies, where other project activities were located, were selected non-randomly (we control for non-randomly selected villages in all our regressions). In each of the 45 villages, farm households were randomly sampled proportional to village size, resulting in a total sample of 683 households. The first survey wave was carried out in 2012, followed by two additional waves in 2015 and 2018. Over the 6-year period, we experienced sample attrition of 10%, mostly due to outmigration or household dissolution after cases of death, divorce, or other reasons. We find no systematic differences in key variables between attrition households and the rest of the sample (Table S1).¹ For the analysis, we use the balanced panel of 615 households observed in all three survey

¹We also carried out a regression-based test for attrition bias as suggested by Wooldridge (2010). Results are shown in Table S2. The dummy testing for attrition bias is statistically insignificant.

waves (1845 observations). The sample can be considered representative of family farm households in the lowland areas of Jambi.

In all three survey waves, we used structured questionnaires for personal interviews with the household head. The interviews were always carried out between September and December in Bahasa Indonesia by a team of local interviewers who were trained and supervised by the researchers. The questions covered topics related to farm production and other income-generating activities over the past 12 months. Furthermore, data on household demographics, assets, and other socioeconomic and contextual variables were collected, including a section on household consumption with a detailed breakdown of food and non-food goods and services.

2.2 | Conceptual framework

The large majority of farm households in our sample grow either rubber, or oil palm, or both. In addition, a few farmers grow small plots with food crops. However, due to the higher profitability of rubber and oil palm and the good accessibility to purchased food from the market, food crop production has become rather uncommon in the lowland areas of Jambi. We are particularly interested whether cultivating oil palm affects household welfare and economic risk in comparison to cultivating rubber as the more traditional cash crop. In other words, we analyse the effects of adopting oil palm on household welfare and economic risk.

In general, we can assume that a farmer decides to cultivate a new crop only if this crop is more profitable and adds to household income. However, both rubber and oil palm are crops that require relatively large initial investment for plantation establishment, which then produce for several decades. Hence, farmers' profitability expectations at the time of the initial adoption decision may be wrong, or the profitability may change with evolving prices on international commodity markets. Moreover, oil palm cultivation may have spillovers to other household economic activities. Using farm-level data from Jambi, Euler et al. (2017) showed that oil palm does not have higher average gross margins than rubber per hectare of land, whereas the return to labour is significantly higher, as oil palm requires much less labour per hectare than rubber, especially less family labour (Chrisendo et al., 2020; Krishna, Euler, et al., 2017; Rist et al., 2010). This is also reflected in our data (Figure S1), which show that rubber uses more than four times the labour required for oil palm. Hence, farm households cultivating oil palm instead of rubber (or switching from rubber to oil palm) can reallocate labour to other economic activities, either on-farm or off-farm.

On-farm labour reallocation allows oil palm farmers to expand their farm activities and cultivate additional land, providing that additional land is available and accessible, which is true in many parts of Jambi. Kubitzka, Krishna, Urban, et al. (2018) showed that forest clearing has been a common way for farm size expansion in Jambi in recent decades. In addition, land market transactions have become common, especially in regions where forestland is scarce (Krishna, Kubitzka, et al., 2017). Several earlier studies suggest that oil palm adoption contributes to farm size expansion in a causal way, partly driven by the lower labour requirements per hectare of land (Krishna, Euler, et al., 2017; Kubitzka, Krishna, Alamsyah, et al., 2018).

Off-farm labour allows oil palm farmers to pursue wage employment or self-employed business activities. Indeed, many farm households in Jambi have off-farm jobs or businesses in transport, trade, or other types of services (Chrisendo et al., 2020). Earnings from off-farm activities contribute to total household income and welfare. Moreover, off-farm income can help to smooth total income and consumption and thus reduce downside economic risk, especially in years with low agricultural commodity prices.

How exactly the saved labour time of oil palm adopters is used will depend on many factors, including access to land, capital, and education, all of which may vary between households. In any case, it is clear that looking at gross margins or profits per hectare alone would be

insufficient to capture the broader welfare effects of oil palm adoption. The different mechanisms are explicitly considered in our regression models below.

2.3 | Estimating effects of oil palm on household welfare

Our first research objective is to evaluate the average welfare effects of oil palm cultivation over the 6-year time period covered by the survey. We measure welfare in terms of annual household consumption expenditure (including the value of purchased and home-produced goods). Especially among rural households in developing countries, consumption expenditures are usually considered a better indicator of living standard than income (Deaton, 1997). Consumption expenditures are expressed per adult equivalent (AE) and deflated to 2012 prices using consumer price indices. To estimate the effect of oil palm cultivation (adoption), we use the following regression model:

$$C_{i,t} = \beta_0 + \beta_1 \text{OP}_{i,t} + \beta_2' \mathbf{X}_{i,t} + \varepsilon_i + \sigma_{i,t} \quad (1)$$

where $C_{i,t}$ is consumption expenditure of household i at time t , $\text{OP}_{i,t}$ is a dummy variable indicating whether or not household i cultivated oil palm at time t , $\mathbf{X}_{i,t}$ is a vector of control variables, ε_i is a household specific time-invariant error term, and $\sigma_{i,t}$ is a time-varying error term.²

We use a log-transformation of consumption expenditures for a better empirical fit. As mentioned above, households in our sample that do not cultivate oil palm grow rubber (some also grow both cash crops). Hence, the coefficient β_1 measures the effect of oil palm adoption/cultivation on consumption expenditures in percentage terms, using rubber farmers as the reference group. If oil palm has a positive effect on household welfare, β_1 would be positive and significant.

In terms of the control variables $\mathbf{X}_{i,t}$, we include socioeconomic variables such as the household size, the number of adults, the age, sex, and education level of the household head, asset ownership, access to credit and remittances, and market distance, among others. We also control for whether or not the village in which the farm household lives was founded as part of the government's transmigration programme. Finally, we include survey year dummies to control for time fixed effects, such as changes in weather conditions or commodity prices. As all households were sampled in the lowland regions of Jambi, where soil, climate, and topographical conditions are similar, regional differences in the suitability for oil palm and rubber cultivation are negligible. Specific definitions of all variables used in the regressions are shown in Table S3.

The asset variables, such as farm size and ownership of other household assets, deserve further discussion. On the one hand, larger farms and wealthier households, who have higher consumption expenditures anyway, may be more likely to adopt oil palm. Hence, not controlling for these asset variables could lead to an overestimation of the effects of oil palm adoption in Equation (1). On the other hand, as explained above, the labour savings associated with oil palm adoption can also allow farm size expansion and off-farm activities. In that case, controlling for current asset ownership at the time of the survey might lead to an underestimation of the effects of oil palm adoption. We address this problem by controlling for initial farm size and initial wealth prior to the widespread adoption of oil palm in Jambi, for which we obtained data in the survey through recall questions.³ Initial farm size is measured in hectares. Initial household wealth is measured through an asset-based wealth index. As suggested by

²In addition to the dummy variable specification of $\text{OP}_{i,t}$, we also run models with the share of the total farmland under oil palm as a robustness check, to account for differences in the scale of operation and the level of specialisation.

³For some of the households, data on initial farm size and wealth are missing so that the number of observations slightly drops to below 1800 for the three-wave panel models.

Filmer and Pritchett (2001), we employ principal component analysis to construct the wealth index using information on past ownership of different types of assets, including mobile phones, motor cycles, cars, air conditioners, fridges, washing machines and televisions. Based on this index, we construct five wealth quintiles. A variable capturing these initial wealth quintiles is included in Equation (1).

To gain further insights into the mechanisms underlying the oil palm adoption effects on consumption expenditures, we include additional control variables in a stepwise manner. First, we add current farm size, which is often different from initial farm size. If it is true that oil palm adoption causes some farmers to expand their farmland, the coefficient for current farm size would likely be positive, whereas the oil palm coefficient itself would shrink. Second, we add variables to test the off-farm employment mechanism. Off-farm activities are captured through two variables, namely the number of wage employments and owned businesses within a household. In the absence of data on the exact time spent in different off-farm activities, looking at the number of own businesses and jobs seems appropriate, as most off-farm activities in rural Jambi are rather informal and related to businesses that have limited potential to grow, such as managing small shops, services in transport, working as a driver, or sometimes also working on other farms. Hence, if family members have additional time available they will likely start an additional business or job rather than investing much more time into already existing off-farm activities.

2.4 | Estimating effects of oil palm on downside risk

Our second objective is to evaluate whether oil palm cultivation contributes to downside economic risk. Again, we use household consumption expenditures as our welfare measure but now pay explicit attention to expenditure variation over time. Even though the farm households in Jambi often do not belong to the poorest of the poor, many of them are moderately poor and therefore vulnerable to income shocks. We are particularly concerned about negative income and consumption shocks (Townsend, 1995). Hence, we analyse whether oil palm cultivation influences the probability of declines in consumption expenditures using the following model:

$$\text{Prob}(C_{i,t} < C_{i,t-1}) = \gamma_0 + \gamma_1 \text{OP}_{i,t} + \gamma_2' \mathbf{X}_{i,t} + \varepsilon_i + \sigma_{i,t} \quad (2)$$

where $C_{i,t-1}$ is consumption expenditure in the previous time period, and the other variables are as defined above. As our survey was conducted with 3 years between the different waves, we compare expenditures in the survey year with those 3 years earlier. As lagged expenditures are required, we estimate this specification only with observations from the 2015 and 2018 waves, using 2012 and 2015 lagged expenditure values respectively. A positive and significant coefficient γ_1 would indicate that oil palm cultivation increases the probability of downside risk, whereas a negative coefficient would point at a decreasing effect on risk. Due to the binary nature of the dependent variable, we use a logit estimator.

Again, we estimate this model in Equation (2) with and without farm size and off-farm income activities included in the vector $\mathbf{X}_{i,t}$, to better understand the impact mechanisms. Off-farm activities are of particular interest here, as access to off-farm income may help to smooth household consumption in years with unfavourable agricultural prices or weather conditions.

2.5 | Dealing with endogeneity

The models in Equations (1) and (2) can be estimated with a random effects (RE) panel estimator. However, one potential issue with RE estimates is that they are biased when explanatory

variables are correlated with the error term. Such correlation is possible especially for oil palm cultivation, $OP_{i,t}$, as farmers decide themselves whether or not to adopt based on various observed and unobserved characteristics. In these cases, the fixed effects (FE) estimator is preferred, as it controls for time-invariant unobserved heterogeneity, thus reducing endogeneity bias (Wooldridge, 2010). We use the Hausman (1978) test to compare RE and FE specifications and to choose the most appropriate estimator.

One drawback of the FE estimator is that it is less efficient than the RE estimator, especially when the variation of key variables within households over time is small. In our case, variation in the oil palm cultivation dummy over time is not very large; between 2012 and 2018 the proportion of farm households cultivating oil palm increased from 35% to 46%. In that case, the correlated random effects (CRE) estimator, which is often also called pseudo fixed effects, is a more efficient choice (Mundlak, 1978). The CRE model controls for time-invariant unobserved heterogeneity through including household-level time means of all time-variant explanatory variables. Because these time means are held constant, the coefficients of the explanatory variables themselves only capture the within variation, similar to the standard FE model.

3 | RESULTS

3.1 | Descriptive statistics

Table 1 presents descriptive statistics of key variables in 2012, 2015 and 2018. The average farm in our sample has a size of 4 hectares with a slight increase observed over time. The share of farmers cultivating oil palm has increased since 2012, and so has the average oil palm area per farm. Analogously, the average area grown with rubber has decreased, even though rubber remains the dominant crop. In terms of living standard, the average farm household had annual consumption expenditures of 14.5 million Indonesian rupiah (IDR) per adult equivalent (AE) in 2012, which is around US\$1540.⁴ The mean expenditure level was lower in 2015, but then increased again until 2018 (all deflated to 2012 price levels).

Figure 1 shows factory-gate prices for oil palm fresh fruit bunches (FFB) and rubber in Jambi for the 2012–2018 period, indicating considerable price volatility. Both prices were significantly lower in 2015 than in 2012. Although the price decline during this period was more pronounced for rubber, the price for oil palm FFB showed larger fluctuations. By 2018, both prices were again higher than in 2015. As oil palm and rubber are the main income sources of farm households in Jambi, these output price variations can partly explain the changes in consumption expenditures over time. However, the consumption expenditures between 2015 and 2018 increased more than the oil palm FFB and rubber prices. Moreover, Figure 2 shows that the 2015 decline in consumption expenditures was only observed among the rubber farmers and not the oil palm adopters, suggesting that commodity price trends are not the only factors influencing household living standard. Indeed, Table 1 shows that the share of households running a small business and also the total number of businesses per household increased over time, which is especially true among the oil palm adopters. Similarly, off-farm activities also gained in importance, especially between 2012 and 2015, possibly to compensate for lower oil palm and rubber prices and revenues.

Table 2 compares two subsamples over time, namely households that cultivated oil palm already in 2012 (early oil palm adopters) and those that had not cultivated oil palm during any of the survey years (non-adopters). Early oil palm adopters show an increase in mean farm size over time, whereas it decreases for the non-adopters. Furthermore, both subsamples show an

⁴Around 10% of the farm households fall below the extreme international poverty line of \$1.90 per capita and day; around 45% are classified as moderately poor (<\$3.20).

TABLE 1 Descriptive statistics for key explanatory variables

	2012		2015		2018	
	Mean	SD	Mean	SD	Mean	SD
Current farm size (ha)	3.94	(4.35)	3.99	(4.65)	4.07	(4.85)
Cultivates oil palm (0/1)	0.35	(0.48)	0.37	(0.48)	0.46	(0.50)
Cultivates rubber (0/1)	0.83	(0.38)	0.81	(0.39)	0.78	(0.42)
Oil palm area (ha)	1.02	(2.53)	1.16	(2.76)	1.44	(3.11)
Rubber area (ha)	2.73	(3.10)	2.72	(3.82)	2.52	(3.37)
Consumption expenditure (million IDR/AE/year)	14.47	(19.66)	13.90	(10.65)	15.18	(15.73)
Own business (0/1)	0.19	(0.39)	0.26	(0.44)	0.26	(0.44)
Number of own businesses	0.22	(0.49)	0.32	(0.57)	0.36	(0.67)
Employed (0/1)	0.46	(0.50)	0.56	(0.50)	0.55	(0.50)
Number of wage employments	0.62	(0.79)	0.81	(0.88)	0.82	(0.93)
Market distance (km)	6.67	(7.46)	5.47	(5.68)	4.72	(5.24)
Observations	615		615		615	

Note: Mean values are shown with standard deviations (SDs) in parentheses.

Abbreviations: 1 USD = 9390 IDR (in 2012); AE, adult equivalent; IDR, Indonesian Rupiah (all monetary values deflated to 2012).

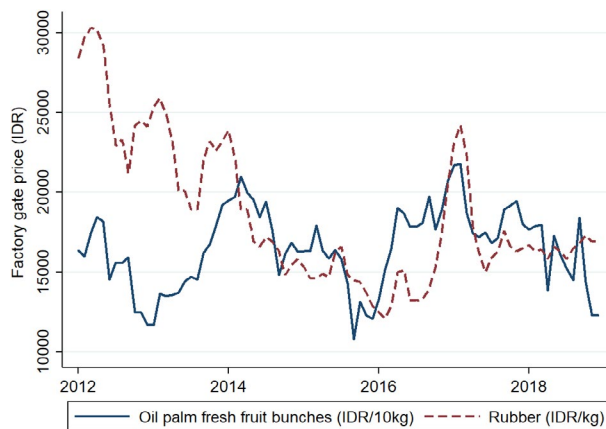


FIGURE 1 Price movement of rubber and palm oil between 2012 and 2018. Rubber price data from Gabungan Perusahaan Karet Indonesia, Jambi. Oil palm fresh fruit bunch price data from Dinas Perkebunan, Jambi

increase in off-farm activities, especially between 2012 and 2015. The increase in self-employed own businesses is much stronger for the early adopters than for non-adopters. These patterns are consistent with our conceptual framework, namely that oil palm adopters reallocate the labour time saved per hectare to expanding their farm size and to off-farm economic activities.

3.2 | Effects of oil palm cultivation on consumption expenditures

Table 3 presents estimation results of the consumption expenditure model (Equation 1), with consumption expenditures per AE expressed in logs as dependent variable. The Hausman test rejects the null hypothesis that the RE estimator leads to unbiased results ($p = 0.037$), so we

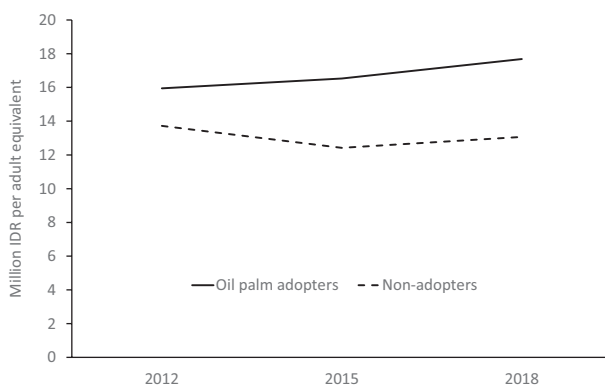


FIGURE 2 Mean consumption expenditures among oil palm adopters and non-adopters (2012–2018)

TABLE 2 Comparison of early oil palm adopters and non-adopters

	Early oil palm adopters (had adopted oil palm before 2012)			Non-adopters (had not adopted oil palm until 2018)		
	2012	2015	2018	2012	2015	2018
Current farm size (ha)	5.20 (5.00)	5.41 (5.29)	5.59 (5.62)	3.05 (2.86)	2.86 (2.79)	2.76 (2.87)
Number of own businesses	0.26 (0.54)	0.40 (0.68)	0.40 (0.72)	0.21 (0.46)	0.26 (0.50)	0.29 (0.61)
Number of wage employments	0.59 (0.81)	0.79 (0.81)	0.75 (0.87)	0.68 (0.80)	0.87 (0.92)	0.93 (0.99)
Observations	214	214	214	307	307	307

Note: Mean values are shown with standard deviations in parentheses.

use the CRE specifications for all models shown. Column (1) is the base model, which does not include current farm size and off-farm activities as expected impact mechanisms. The coefficient of 0.13 for oil palm suggests that cultivating this crop is associated with a 13% increase in consumption expenditures on average.

In the other columns in Table 3, we analyse some of the impact mechanisms. As mentioned, oil palm requires much less labour per hectare than rubber or alternative crops, so that oil palm farmers can reallocate some of the family labour saved to cultivating additional land or to off-farm activities. In column (2) we control for current farm size, in columns (3) and (4) for different off-farm activities, and in column (5) we jointly control for current farm size and off-farm activities. In most models, these farm and off-farm activities are positively associated with consumption expenditures, as one would expect. Especially own business activities seem to be quite lucrative. On average, each additional business helps to increase consumption expenditures by 12% (column 3). At the same time, the oil palm cultivation coefficient decreases in magnitude.

These results confirm that a large part of the welfare benefits of oil palm cultivation is channelled through farm size expansion and additional off-farm activities. After controlling jointly for the different mechanisms, the direct effect of oil palm cultivation becomes statistically insignificant (column 5 in Table 3). This is in line with earlier research showing that the average gross margin per hectare of oil palm is not higher than that of rubber (Euler et al., 2017). Alternative model specifications with oil palm measured in terms of the share of the farmland area cultivated with this crop are shown in Table S4. These additional results confirm the

TABLE 3 Effects of oil palm cultivation on consumption expenditures

	(1)	(2)	(3)	(4)	(5)
Cultivates oil palm (0/1)	0.13*** (0.05)	0.09** (0.05)	0.11** (0.05)	0.13*** (0.05)	0.07 (0.05)
Current farm size (ha)		0.03*** (0.01)			0.03*** (0.01)
Number of own businesses			0.12*** (0.03)		0.13*** (0.03)
Number of wage employments				0.02 (0.02)	0.04* (0.02)
Household size	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.10*** (0.02)	-0.10*** (0.02)
Number of adults	0.03 (0.02)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.01 (0.02)
Education household head (years)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
Age household head	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)
Female head (0/1)	-0.19*** (0.07)	-0.18*** (0.07)	-0.17** (0.07)	-0.20*** (0.07)	-0.18*** (0.07)
Transmigrant village (0/1)	-0.00 (0.03)	0.02 (0.03)	0.02 (0.03)	-0.00 (0.03)	0.04 (0.03)
Non-random village (0/1)	0.11** (0.05)	0.08* (0.05)	0.11** (0.05)	0.11** (0.05)	0.07 (0.05)
Market distance (km)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)
Initial farm size (ha)	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)
Initial wealth quintile (1-5)	0.11*** (0.01)	0.09*** (0.01)	0.08*** (0.01)	0.11*** (0.01)	0.06*** (0.01)
Credit access (0/1)	0.10*** (0.03)	0.10*** (0.03)	0.10*** (0.03)	0.10*** (0.03)	0.09*** (0.03)
Remittances (0/1)	-0.04 (0.07)	-0.04 (0.07)	-0.05 (0.07)	-0.04 (0.07)	-0.05 (0.07)
Survey round 2015 (0/1)	-0.05** (0.03)	-0.05** (0.03)	-0.06** (0.03)	-0.05** (0.03)	-0.07*** (0.03)
Survey round 2018 (0/1)	-0.03 (0.03)	-0.02 (0.03)	-0.04 (0.03)	-0.03 (0.03)	-0.04 (0.03)
Time means included ^a	Yes	Yes	Yes	Yes	Yes
Observations	1783	1783	1783	1783	1783

Note: Results of correlated random effects (CRE) models with annual consumption expenditures per adult equivalent (expressed in log form) as dependent variable. Coefficient estimates are shown with robust standard errors in parentheses.

^aMeans over time of all time-varying observables are included.

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

positive welfare effects of oil palm cultivation and the relevance of the farm size expansion and off-farm activity mechanisms.

In Table S5, we look more specifically at impact dynamics by estimating the effects of oil palm cultivation separately for each of the three survey waves. These are OLS regressions,

so that endogeneity may potentially be an issue. Nevertheless, the estimates suggest that the welfare effects of oil palm cultivation vary over time. The largest effects were observed in 2015. This is interesting because in 2015 the prices of both palm oil and rubber were particularly low. Due to the lower labour requirements in oil palm, farmers growing this crop are better able to cope with decreases in farm revenues through reallocating more of their labour time to off-farm activities. It is important to note here that the welfare effects in our models are evaluated with rubber farmers as the reference group.

3.3 | Effect of oil palm cultivation on economic risk

Table 4 shows estimation results of the downside risk model (Equation 2), with a dummy for consumption expenditure declines as the dependent variable. The Hausman test fails to reject the null hypothesis that the RE estimator leads to unbiased results ($p = 0.866$), so that we use an RE logit estimator. The estimates shown in Table 4 can be interpreted as marginal effects. Column (1) shows results of a model where we do not control for the impact mechanisms. The estimate of -0.06 suggests that oil palm cultivation reduces the probability of downside economic risk by six percentage points. As discussed above, one reason for the risk-reducing effect is that oil palm adopters have more time available to earn off-farm income. This mechanism is further supported by the results in column (2) of Table 4, where especially the number of own businesses significantly decreases downside risk.⁵

In Table 5, we summarise results from additional regression models, where off-farm activities are explained by oil palm cultivation and other control variables. As the dependent variables in these models are count variables (number of own businesses and employed jobs), we use a Poisson CRE specification. Oil palm cultivation has a positive and significant effect on own business activities (column 1), whereas the effect on the number of employed jobs is statistically insignificant (column 2).

4 | DISCUSSION AND CONCLUSION

The rapid expansion of oil palm in tropical regions is sometimes associated with socio-economic problems, including land conflicts between large palm oil companies and local communities. However, in Indonesia much of the oil palm land is managed by family farms. In this article, we use three waves of panel data collected over a period of 6 years on the Indonesian island of Sumatra to analyse whether oil palm cultivation contributes to average welfare gains among smallholder farmers. Regression models with pseudo fixed effects showed that oil palm cultivation raises household living standards by 13% on average, after controlling for possible confounding factors. Oil palm requires much less labour per hectare than rubber or other alternative crops, allowing oil palm farmers to expand their farm activities or to pursue more off-farm economic activities. Both these mechanisms contribute to the gains in income and consumption expenditure.

These results are consistent with earlier research that analysed the effects of oil palm cultivation on smallholder welfare (e.g., Euler et al., 2017; Feintrenie et al., 2010; Krishna, Euler, et al., 2017). However, these previous studies used cross-sectional data, where endogeneity is more difficult to control. Moreover, because commodity prices are subject to international price fluctuations, data from just 1 year may potentially be misleading. Our panel data results

⁵The same findings are also confirmed in alternative model specifications where oil palm cultivation is measured in terms of the share of the farmland under this crop (Table S6). Figure S2 shows that the contribution of off-farm income varies over time and was particularly high in 2015, when agricultural commodity prices were low. This is another clear indication that off-farm earnings are used by farm households to smooth total income and consumption.

TABLE 4 Effects of oil palm cultivation on downside economic risk

	(1)	(2)
Cultivates oil palm (0/1)	-0.06** (0.03)	-0.06** (0.03)
Current farm size (ha)		0.00 (0.00)
Number of own businesses		-0.04* (0.02)
Number of wage employments		0.00 (0.02)
Household size	0.01 (0.01)	0.01 (0.02)
Number of adults	0.04* (0.02)	0.04* (0.02)
Education household head (years)	0.00 (0.00)	0.00 (0.00)
Age household head	0.00 (0.00)	0.00 (0.00)
Female head (0/1)	0.05 (0.05)	0.05 (0.05)
Transmigrant village (0/1)	0.06** (0.03)	0.05* (0.03)
Non-random village (0/1)	0.00 (0.04)	-0.00 (0.04)
Market distance (km)	0.00 (0.00)	0.00 (0.00)
Initial farm size (ha)	0.00 (0.00)	0.00 (0.00)
Initial wealth quintile (1-5)	0.01 (0.01)	0.01 (0.01)
Credit access (0/1)	0.02 (0.03)	0.02 (0.03)
Remittances (0/1)	0.10* (0.06)	0.11* (0.06)
Survey round 2018 (0/1)	-0.09*** (0.03)	-0.09*** (0.03)
Observations	1187	1187

Note: Results of random effects (RE) logit models with a dummy indicating whether or not annual consumption expenditures were lower than in previous survey wave (3 years ago) as dependent variable. Only observations from 2015 and 2018 included. Average marginal effects are shown with robust standard errors in parentheses.

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

are more robust and confirm that oil palm cultivation is welfare-enhancing for smallholder farmers, controlling for endogeneity and accounting for price fluctuations.

A second objective was to analyse whether oil palm cultivation affects downside economic risk. Given the observed price fluctuations on international palm oil markets, it could be expected that oil palm farmers are more vulnerable to income variations and temporary decreases in living standards. However, our data showed the opposite, namely a decrease in downside economic risk through oil palm cultivation. The main reason is that oil palm adopters have

TABLE 5 Effect of oil palm cultivation on off-farm activities

	(1)	(2)
	Number of own businesses	Number of wage employments
Cultivates oil palm (0/1)	0.17*** (0.06)	0.01 (0.07)
Other control variables included	Yes	Yes

Note: Marginal effects from correlated random effects (CRE) Poisson models are shown with robust standard errors in parentheses. Full model results are shown in Table S7.

***Significant at 1% level.

more time for off-farm activities than rubber farmers, and off-farm income is an important household mechanism to cope with economic risk. The important role of off-farm income for reducing income risk of rural households in developing countries is well established (Barrett et al., 2001; Morduch, 1994; Townsend, 1995), but had not previously been shown for households that cultivate oil palm. In our study setting, self-employed off-farm business activities seem to be more important than employed jobs. Indeed, we showed that oil palm cultivation increases the number of own businesses that a household operates, even after controlling for initial wealth levels. The same effect was not observed for employed off-farm activities, which is likely due to the limited availability of lucrative off-farm jobs in rural Sumatra.

Overall, our results suggest that oil palm cultivation has positive economic and social effects in the small farm sector of Sumatra. Although studies with country-wide data show that oil palm helps to reduce poverty and promotes economic growth in Indonesia also more generally (Edwards, 2019; Krishna & Kubitzka, 2021; Kubitzka & Gehrke, 2018), our micro-level results from Sumatra cannot be generalised. A recent study with data from Kalimantan suggests that not all local communities benefit to the same extent from the recent oil palm boom (Santika et al., 2019). Unlike Sumatra, where much of the oil palm land is cultivated by smallholders, in Kalimantan large palm oil companies play a more dominant role. Another important difference is that smallholder farm households in Sumatra have long been quite market-oriented, whereas many farmers in Kalimantan are still more subsistence-oriented. Depending on the context, oil palm adoption and cultivation can have different effects on local communities (Cramb & McCarthy, 2016).

Our results have some important policy implications, not only for Indonesia but also more generally, as oil palm is now also expanding in other parts of the world, especially in Africa (Byerlee et al., 2017). First, oil palm cultivation can contribute to welfare gains for smallholder farmers without increasing economic risk, so long as palm oil supply chains are smallholder-inclusive. Smallholder involvement can be supported through strengthening land property rights for local farmers and communities and through improving smallholder access to credit, technologies and technical support. Second, as the welfare effects of oil palm also depend heavily on farm households' access to off-farm activities, policies should strengthen rural off-farm development. In our study, oil palm farmers reallocated some of the labour time saved to self-employed business activities, but the availability of lucrative off-farm jobs is limited in rural Sumatra. More off-farm jobs could further improve the welfare effects and also help smallholder farmers to better cope with economic risk.

Finally, our study also has some research implications. First, although we improved on previous cross-section evaluations through using three waves of panel data collected over a period of 6 years, analysing welfare dynamics in more detail would benefit from longer panels. Second, longer-term studies in different regions would help to illuminate the role of varying institutional factors. Third, although economic and social effects are two important dimensions

of sustainability, the environmental dimension must not be neglected. Recent studies suggest that oil palm in diverse smallholder landscapes may be more environmentally friendly than large-scale monoculture plantations (Qaim et al., 2020). More research that jointly considers the various sustainability dimensions is certainly warranted.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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