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Cash crops as a sustainable pathway out of poverty? Panel data evidence on the heterogeneity of cocoa farmers in Sulawesi, Indonesia

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The cultivation of cash crops has a great potential for reducing poverty in the developing world that may not be fully harnessed because many smallholders are inefficient producers. Further, income gains may be only static and poverty and vulnerability of smallholder households may not be reduced sustainably. Instead, cash crop farmers, in particular those without proper farm management skills, may experience boom and bust cycles, caused by volatile world market prices local weather shocks and pests. To analyze the long-term poverty impacts of cash crop agriculture, we draw on a unique panel data set of smallholder cocoa farmers in Central Sulawesi, Indonesia, covering the years 2000, 2006 and 2013. We show that – over the analyzed time horizon of more than 10 years – cocoa cultivation is associated with strong and sustainable poverty reduction. Cocoa farmers fare better than non-cocoa farmers and the welfare gains can mainly be attributed to increasing cocoa yields. Yet, yield gaps remain large and are increasingly heterogeneous. We can trace back this productivity heterogeneity to farm management practices. Linking these findings to poverty transitions, we can show that better management practices facilitate the transition out of poverty and shields against income losses.

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I. Introduction

In the developing world, growth originating in the agricultural sector has long been identified as an essential pathway out of poverty. Since 70 percent of world's poor live in rural areas, diversification in cash crops for global food markets has been widely discussed as a prospective route for agricultural growth and poverty reduction (Klasen et al., 2013; Feintrenie et al., 2010; The World Bank, 2007). The cultivation of commercial crops has also been found to foster rural infrastructure and public services which both entail positive effects on broader levels (Vanwambeke et al., 2007; Walker et al., 2002). Hence, increased commercialization within the agriculture sector might be a key driver to transform a semi-subsistence agrarian society to a more diversified economy including off-farm industries and higher levels of welfare (Achterbosch et al., 2014).

Living standards of cash cropping smallholders can be, on average, higher and the long-term income improvements depend highly on the respective technological skills of individual households, in particular agronomic practices (Tittonell and Giller, 2013). However, a successful integration into global crop markets requires the individual ability of poor households to mitigate or cope with the risks associated with cash crop production. These are, among other factors, price shocks as well as marketing and production risks (Wood et al., 2013; Rist et al., 2010; Sunderlin et al., 2001; Barbier, 1989). . The exposure to production and marketing risks faced by smallholders are, to an important extent, determined the specific conditions of input and output markets. These conditions combined with the idiosyncratic capacities and constraints determine the crop choices and production technology chosen by smallholders and, in turn, their risk exposure, in particular to environmental shocks, such as floods, droughts or plant diseases (Chuku and Okoye, 2009). Changing the crop portfolio from subsistence cultivation to intensified cash crop cultivation might increase this risk exposure since it adds the hazards of mono-cropping that can promote and accelerate the incidence of pests (Steffan-Dewenter et al., 2007). The capacity to deal with these hazards depend in particular on farmers' management practices including the timing of operations, the accurate application and composition of chemical inputs and plantation maintenance (Schreinemachers et al., 2015; Chuku and Okoye, 2009; Sabatier et al., 2013). It is well known that the capacity of smallholders to apply optimal management practices is limited, as are other means to cope with shocks, for example through credit markets (Harvey et al., 2016; OECD, 2015). As a result, the income gains of cash crop farming may be volatile and the long-term benefits smaller than the well-documented short-term gains (Klasen et al., 2013; Carletto et al., 2009; Tittonell et al., 2007). Empirical evidence, however, on the long-term impact of cash crop farming remains scarce, in particular since such assessments require long-term panel data.

This paper addresses this gap by examining the long-term welfare impacts of smallholder cocoa farming. Our analysis draws on a unique three-wave panel data set of smallholder cocoa farmers in Central Sulawesi, Indonesia, which spans a period of 13 years. We first analyze income dynamics and poverty changes over this period comparing cocoa- and non-cocoa farmers. As cocoa yield improvements, as the key driver of increasing cocoa incomes, were accompanied by a higher variation in yields, we then look at the determinants of cocoa yields. This analysis allows us to distinguish between smallholders according to their management practices; a distinction that we, in a final step, use to assess whether well-managing farmers are faring better than those who fail to do so.

The paper is structured accordingly. We first provide a literature review on the welfare impacts of cash crop cultivation. After providing some background information on Indonesia, its cocoa sector and the study region, we describe the data. Our empirical analysis then looks into welfare changes, determinants of cocoa yields, and the influence of management skills on welfare trajectories. We close with summarizing our main results and suggestions for future research.

II. Literature review and research questions

In the transition from a low productivity, semi-subsistence agriculture to a high productivity, commercialized agriculture (Timmer, 1988), cash crops can serve as a potential route for agricultural growth and thus poverty reduction in bringing substantial productivity increases and employment opportunities to the rural economy. Transforming sectors can stimulate agricultural innovation by raising capital for agricultural investment and accelerating the build-up of institutions that enable further commercialization (Achterbosch et al., 2014).

For cash crops to be also a successful driver of poverty reduction, the transition from subsistence to commercial agriculture significantly depends on the participation of smallholder farmers who typically farm less than two hectares in developing countries (The World Bank, 2007). Feintrenie et al. (2010) find that cash crops with low labor requirements and the absence of seasonality are most lucrative for traditional smallholder farmers. Then, cash crops can be easily integrated into the already prevailing farming systems through, for example, the planting of agroforests or the intercropping of new cash crops with previously cultivated crops. Moreover, fragmented markets let smallholders' choices to be non-separable for production and consumption. Decisions on cash- and food crops are thus inter-linked and agricultural commercialization has therefore been found to have positive spill-over effects on households' food production (Govereh and Jayne, 2003). In turn, many farm households mitigate production risks of cash crops and vulnerability to price variability through diverse livelihoods relying also on food crop production or non-farm income (Eriksen et al., 2005). However, once markets for labour and inputs develop, intercropped areas are often converted into more intensified, productive land-use systems, possibly increasing farmers' exposure to shocks.

The benefits from cash crop farming have been shown, for example, by Bussolo et al. (2007) for the case of Uganda. They find that – in the 1990s – coffee market liberalization followed by a price boom was associated with substantial reductions in poverty that could be sustained when prices went down again.

Cash crop cultivation has also been found to be poverty reducing by Klasen et al. (2013). Based on shorter panel of the same households used in this paper (2001, 2004 and 2006), they show that households cultivating cocoa were on average able to achieve about 14 percent higher income levels compared to cultivating other crops. The authors suggest that the switch to cocoa might be a strategy to raise income especially for the poorer segments of rural populations.

In contrast, Carletto et al. (2009) present evidence on negative long-term welfare effects of agricultural commercialization.. The authors focus on households' adoption of a non-traditional, agricultural export crop (snow pea) in the Central Highlands of Guatemala and use panel data between 1985 and 2005. Applying difference-in-differences estimation, the results suggest that while consumption levels have improved for all households in the surveyed communities, long-term cash crop adopters show on average lower gains with higher benefits only in the beginning. The authors point at to agronomic problems

– in addition to marketing and institutional problems – leading to decreasing profitability in snow pea production.

Weak management practices – combined with input and output market failures – are the main cause behind such deficits and the considerable yield gaps of smallholder production in many cash crops around the world (Mueller et al., 2012; Neumann et al., 2010; Tittonell et al., 2007; Tittonell and Giller, 2013). The relationship between practices and yields, however, will depend on the specific crop and region and might be non-linear across scales. On the global level, Mueller et al. (2012) assess the link between yield variability and agricultural management using input-yield models. They postulate as key causes for worldwide yield gaps irrigation techniques, fertilizer application and climate condition – together the three factors explain 60-80 percent of global yield variability for most of the major global crops. Complementary to this, studies on the regional and local level give insights into more subtle drivers of crop yield-gaps. For example, Neumann et al. (2010) estimate regional frontier yields to compute frontier production and inefficiencies in wheat, maize and rice cultivation. For Indonesia, they find that the variance in efficiency comes mostly from differences in market accessibility and availability of agricultural labor. Examining a more detailed case, Tittonell et al. (2007) explore maize yield gaps on the field-level, analyzing within-farm differences of smallholder farms in Kenya. They show that variability of yields stems from soil and climate conditions, the land use change history of fields, and also from the operational management, such as planting time and density or timing of weeding. For selected African countries, Tittonell and Giller (2013) analyze yield-gaps of smallholder farming systems. They conclude that the lack of inputs such as machinery, labor and capital are the main sources of production inefficiencies. However, the authors suggest that – even in the absence of inputs like fertilizer – proper agronomic management, such as cultivars, plant spacing and weeding, is able to narrow yield gaps.

The brief literature review illustrates that the long-term implications of cash crop production and the link to productivity heterogeneity remain underexplored. Using a panel sample of smallholders in a cocoa-growing region in Sulawesi, Indonesia, we therefore examine how cocoa farmers fare vis-à-vis other farmers over a longer time horizon. We also explore the determinants of cocoa yield and investigate whether bad or improved management practices are associated to the sustainability of the benefits of cash crop cultivation.

III. Cocoa in Indonesia and the study region

In the last decades, Indonesia has emerged as a key exporter of agricultural products on global markets. Since the late 1960s, Indonesia experienced high and sustained economic growth, partly driven by the development of its agricultural sector – specifically promoting export oriented agricultural production (Feintrenie et al., 2010; Timmer, 2007; Mundlak et al., 2002). The vast expansion of the agricultural area, the adoption of subsidized technologies, such as irrigation, fertilizer, pesticides and improved seeds, were important drivers of this development that shifted cropping patterns towards the cultivation of cash crops and pushed commercialization (Maertens et al., 2006; Mundlak et al., 2002). The country's agricultural sector thus experienced a transformation from traditional cultivation systems (slash- and burn cropping systems and agroforestry) towards intensified monoculture plantations with cash crops such as coffee, cocoa, coconut, oil palm, and rubber (Feintrenie et al., 2010). In 2014, the agricultural sector contributed about 35 per cent to national employment (The World Bank, 2016a). One of the main agricultural exports of Indonesia are cocoa products, after palm oil, rubber and coffee, representing an exported value of 450 million USD in 2013 (BPS Statistics Indonesia, 2016b). Indonesia, which started to produce cocoa in the 1980s, now is the third largest producer and exporter of cocoa beans in the world, after the Ivory Coast and Ghana (ICCO, 2012). The country's total production of cocoa beans makes 709,330 tons for 2014 and smallholder farms contribute most to national cocoa production covering in total 1,198,962 hectares for cocoa plantations in the same year (BPS Statistics Indonesia, 2016c). The main locations of cocoa production in Indonesia are Sulawesi, North-Sumatra, West Java, Papua, and East Kalimantan. In Sulawesi, smallholder farmers have started to cultivate cocoa beans extensively in the early

1990s (Akiyama and Nisho, 1997). Sulawesi contributes today with a production of over 456,360 tons (2014) the biggest part to the national cocoa production (BPS Statistics Indonesia, 2016c). Our study focuses on the Lore Lindu region, which is part of the province Central Sulawesi and located south of Palu, the capital of this province. The region is predominantly rural and characterized by a high degree of diversity with respect to its geographical and climate conditions (Maertens et al., 2006). The region's centrally located Lore Lindu National Park forms one of the last and largest mountainous rainforests of Sulawesi.

Although cocoa beans are still one of the main exported cash crops, Indonesia's cocoa productivity started to decline in 2005. This decline is mainly attributable to the ageing of cocoa trees and the increasing prevalence of cocoa pests and diseases which smallholder farmers – who account for the majority of plantations – often cannot handle due to the lack of plot management expertise (Nuryartono and Khumaida, 2016). The most common pest in Sulawesi is the Cocoa Pod Borer (CPB), which already spread in the early 2000s (Neilson, 2007). In 2007, farmers of the Lore Lindu region (LLR) report a yield loss of on average 24.3 percent due to the cocoa pod borer and also 20.5 percent due to the black pod disease (Juhrbandt et al., 2010). By the mid-2000s, decreasing cocoa yields – reinforced by aging plantations – had been perceived as a crisis in the sector (Clough et al., 2009). In this context, the application of intensification techniques – originally intended to raise yield levels – have been discussed to increase the susceptibility of cocoa trees to pests and diseases: Clough et al. (2009) discuss that specifically full-sun plantations and the corresponding removal of shading trees raise the physiological stress of the trees and make them more susceptible to the Cocoa Pod Borer and the black pod disease. In light of these developments, the cocoa sector in Sulawesi has been considered to follow a "boom and bust cycle" (Ruf and Yoddang, 2004; Clough et al., 2009).[1] This is also reflected in official statistics: Cocoa yields in Central Sulawesi have decreased from about 1 ton in 2002 to 0.7 tons per hectare in 2014 (BPS Provinsi Sulawesi Tengah 2005, 2010, 2015).

The Indonesian government has reacted to these developments with a plan to raise productivity setting itself a target of one million tons of cocoa beans per year by 2013-2014. In particular, the plan intended to address the problems of ageing of trees, insufficient planting material, and the lack of knowledge on plantation

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[1] This concept describes the process, when firstly young cocoa trees are planted within the tropical rainforest, which provides ideal conditions such as fertile soils, shade trees, and low weed pressure (Clough et al., 2009; Rice and Greenberg, 2000). Due to low investment costs economic gains can be realized once the tree matured at the age of 3 to 5 years and continues to produce cocoa until the age of 20-25 years (Wood and Lass, 2001). During the boom phase, other local farmers might be attracted by promising benefits and start to adapt cocoa cultivation. Then, in-migration is triggered to the rainforest frontiers and primarily agroforests are more and more transformed to mono-cropping systems. This process stagnates, when pest and diseases increasingly spread and trees start to age (Clough et al., 2009).

maintenance (Ministry of Industry, Indonesia, 2016). As one policy, the government started the national program “GERNAS” in 2009 to boost cocoa production through intensification, rehabilitation and rejuvenation activities of around 450,000 hectares (BKPM, 2010). However, actual total production in 2014 was only 70.9 percent of the set target. Indonesia’s’ efforts to revive cocoa production thus obviously failed in reaching the achievable yields.[2]

These developments in the cocoa sector took place in a period of relatively favorable world market prices that showed a slight upward trend between 2000 and 2013 (see Figure 1). After 2000, world market prices for cocoa increased and remained – after the food price hike in 2009 – on a level of around 2500 USD per ton, i.e. 2.5 USD per kg. Farm gate prices, derived from the survey data, increase correspondingly and are 30 to 70 US-Cents below the world market prices. Because of unfavorable exchange rate movements, this trend did not translate into rising farm gate prices. Real farm gate prices (in 2001 Indonesian Rupiah (IDR)) fell between 2001 and 2006 and only slightly recovered until 2013.

Insert Figure 1 here.

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[2] Nuryartono and Khumaida (2016) discuss various reasons for the failure of the government program, such as institutional barriers and inadequate assistance of smallholders.

IV. Data and sampling

In the context of two collaborative research centres (STORMA – Stability of Rainforest Margins in Indonesia, and EFForTS – Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems, Indonesia), household panel data have been collected in 2001, 2006 and 2013 in the Lore Lindu region. The surveys include information on socio-demographics, land holdings, agricultural as well as non-agricultural activities, and endowments. Each survey represents a random sample of 13 villages, which were randomly chosen in 2001 out of official village census data with 115 villages (Zeller et al, 2002). Household are then randomly drawn, with the number proportional to village size. In 2006 and 2013, households that split off from their original households and formed a new one within the Lore Lindu region were additionally interviewed and added to the respective sample. In total, the sample includes 316 households in 2001, 380 in 2006 and 387 households in 2013.

We include all households into our analysis that could be interviewed more than once, which gives 300, 338 and 322 observations in 2001, 2006 and 2013 respectively. As cocoa farmer we classify all farmers with a cocoa plantation of at least 0.25 hectare.

V. Cocoa income and poverty dynamics

In the Lore Lindu region, income from crop agriculture is the main livelihood and it has increased significantly in recent years (see Figure 2.2(a)). Per capita household income from crop agriculture has risen from 644,590 Indonesian Rupiah (IDR) in 2001 to 1,605,030 IDR in 2013, implying an annual growth rate of 7.9 per cent over these 12 years.[3] Hence, household income per capita drawn from crop agriculture more than doubles in this period to around 170 USD in 2013 (see Figure 2a).

Cocoa is the central source of agricultural income for many smallholder households in the Lore Lindu region, as it is also discussed by van Edig und Schwarze (2011) and Klasen et al. (2013). Figure 2b shows a large increase in cocoa income over time with an annual growth of on average 11.6 percent in per capita terms.[4]

Insert Figure 2 here.

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[3] Agricultural wage employment only represents a marginal source of income for our sample households. In addition to crop agriculture, non-farm activities also play an increasingly important role for rural incomes.

[4] Rice, the second most important crop, also increased substantially but only generates less than half of the income generated by cocoa cultivation All others crops display only minor income changes in relative terms and did not contribute significantly to increases in income.

Agricultural growth and cocoa expansion was a driving force of poverty reduction in the study region. Table 1 shows the poverty headcount and poverty gap for all farm households, for cocoa and non-cocoa farmers, as well as separately for households that earn at least one third of their income from off-farm employment. Poverty measured by the headcount index declined from 62.33 percent to 32.61 percent for all households over the whole period. Especially notable is the stark decline between 2006 and 2013. The poverty gap, which estimates the depth of poverty and indicates the resources needed to lift the poor out of poverty by perfectly targeted transfers, decreased substantially from 36.30 percent to 17.66 percent.

Insert Table 1 here.

These significant improvements mainly arise from the poverty reduction among cocoa farmers. Table 1 show that poverty levels among cocoa farmers are lower and, poverty reduction much stronger compared to non-cocoa farmers.

Sampled households in the Lore Lindu region primarily shifted towards cocoa cultivation between 2001 and 2006, which is around 10 years later than the farmers in the South and Southwest of Sulawesi While in 2001, 170 out of 300 households grew at least 0.25 hectare of cocoa, the share went up to 221 out of 338 households in 2006. The poverty depth decreased from 31.28 to 18.62 percent during this time while the poverty incidence among cocoa farmers fell from 54.7 percent to 45.3 percent. This underpins the findings of Klasen et al. (2013) that the shift of households towards cocoa did not have a very strong immediate effect on the poverty incidence as cocoa trees had not yet reached their full maturity by 2006. Thus, poor cocoa farmers could increase their incomes and close the poverty gap but were not able to jump out of poverty. Between 2006 and 2013, the shift to cocoa turns out to be highly rewarding, when the cocoa trees developed their full productive potential. During this time, the poverty headcount among cocoa farmers decreased from 45.25 to 23.15 percent and the poverty gap from 18.62 to 11.91 percent. Only households that partly engage in off-farm activities record even lower poverty rates. Cocoa farmers that derive at least one third of their income from off-farm employment show the lowest incidence and depth of poverty of all household groups, as classified in Table 1. However, they also only represent a small share of the sample.

We now complement this static poverty analysis, which suggests an important role for cocoa production for poverty reduction, by poverty transition matrices that exploit the panel structure of our data.

Insert Table 2 here.

Table 2 shows the absolute numbers of cocoa farmers and non-cocoa farmers in different poverty groups and the shares of households changing poverty status (poor vs. non-poor at a poverty line of USD 1/day PPP) by main farming activity (cocoa vs. non-cocoa farming) for the two sample periods 2001-2006 and 2006-2013. In the first period, farmers that cultivated cocoa in 2001 performed better than non-cocoa farmer with a lower share of poor households remaining poor (43.6 percent of all initially poor cocoa farmers) and a higher share escaping poverty while remaining cocoa farmer (45.7 percent). The share of initial non-cocoa farmers who stick to their activity and remain poor is slightly higher with 48.9 percent.

Interestingly, and in line with the above assessment of poverty changes among cocoa farmers, the transition to cocoa cultivation might not pay off immediately: Some initially non-poor non-cocoa farmers switching to cocoa fall into poverty (21.2 percent of all initially non-poor non-cocoa farmers) over the first period. Similarly, 20 percent of initially poor cocoa adopters cannot escape poverty. – Moreover, within the first period cocoa cultivation seems even to raise the vulnerability to poverty: A considerable amount of (initially) non-poor cocoa farmers (33.3 percent) fall into poverty between 2001 and 2006. The first period is thus characterized by more chronic manifestations of poverty and a higher share of non-poor households falling back into poverty.

In the second period, a much more dynamic upward mobility can observed among cocoa farmers: The share of cocoa farmers escaping poverty increases significantly to 58.7 percent (of initially poor cocoa farmers) and is considerably higher than the share of those remaining poor or falling into poverty. This trend holds also for the (initially) non-poor cocoa farmers whose share of farmers remaining non-poor rises from 60.3 percent in the first period to a 79.8 percent in the second period.

Non-cocoa farmers' income levels also improve, but less than for cocoa farmers. The share of non-cocoa farmers escaping poverty or remaining non-poor is substantially lower than for cocoa households. Moreover, the share of non-cocoa households falling into poverty is higher than in the first period.

Hence, the results clearly suggest that cocoa production is a long-term driver of overall poverty reduction. Yet, despite the increasing opportunity to escape poverty between 2006 and 2013, it is important to recognize that an important share of farmers in cocoa remains poor. This heterogeneity in poverty dynamics and outcomes raises questions concerning the individual determinants of cocoa income and its poverty-reducing potential.

VI. Productivity heterogeneity of cocoa farmers

The direct determinants of cocoa income, i.e. cocoa yield, cocoa area and farm gate prices are shown in Table 3.

Insert Table 3 here.

Whereas cocoa area per household is only slightly rising over time, we observe that average productivity increases significantly over the whole sample period. Cocoa yields increase slightly between 2001 and 2006, but more than double between 2006 and 2013, explaining most of the long-term increase in cocoa income over time. A shown above, real cocoa price fell between 2001 and 2006 and recovered somewhat until 2013.

The increase in average cocoa yields in the second period was accompanied by a considerable increase in their variance, i.e. rising heterogeneity. One important explanatory factor for these trends is the yield-cycle of cocoa. The average tree age of cocoa farmers increases from 3.8 years in 2001 (sd = 3.2 years) to 6.3 years in 2006 (sd = 4.1 years) up to 11.2 years in 2013 (sd = 6.3 years). As cocoa trees start to produce at the age of 3 to 5 until the age of 20 to 25 and reach their productivity peak at the age of 10 (Wood and Lass, 2001), the cocoa plantations of the farmers in the study region have on average reached their most productive age in 2013.

The strong variation of yields means that many cocoa farmers are not exploiting full potential yields. Figure 3 illustrates the average yield gap, i.e. the yield potential and the mean achieved yield for four tree age groups. Following van Ittersum et al. (2013), we estimate yield potentials by upper percentiles in the yield distribution from the surveys. We rely on the 90th percentile of yields among our survey farmers to estimate the maximum potential yield. Farmers obtain yield levels that are well below the potential yields for the region: On average, they achieve about half of the yield potential. For example, while the farmer at the 90th yield percentile produces 1280 kilogram cocoa per hectare for cocoa trees aged 5 to 10 years, the average cocoa farmer only achieves 642 kilogram per hectare. Yield gaps are present for all age groups, suggesting that the plantation age is not the only determinant of heterogeneity among cocoa farmers.

Insert Figure 3 here.

We therefore now analyze cocoa yield determinants (or "correlates" acknowledging the limited causal content of this type of exercise) using pooled ordinary least squares (OLS) and static panel data methods (fixed effects model). We estimate the following equation that relates productivity, management practices as well as farm and farmer characteristics:

$$\ln Y_{it} = \alpha + \sum_j \beta_j P_{j,it} + \sum_k \beta_k M_{k,it} + \sum_l \beta_l H_{l,it} + \delta D_{it} + \gamma_i + \lambda_t + \varepsilon_{it}, \qquad (1)$$

where Y_{it} is productivity defined as yield measured in cocoa beans harvested (in kg) per hectare, P is a matrix of j variables of plot characteristics, M is a set of k variables on management practices, H is a set of l household characteristics, D_{it} is a dummy controlling for the presence of pests, λ_t are time fixed effects and ε_{it} is the idiosyncratic error. The fixed effects (FE) model also includes household fixed effects γ_i that control for unobserved and time-invariant characteristics, such as unobservable ability of farmers. Time fixed effects λ_t (year dummies) further capture time-specific shocks common to all households, like time trends in average productivity or weather shocks that affect all households in the same year. All estimations are performed using cluster-robust standard errors. Summary statistics on the key variables used in our econometric analyses are given in the Appendix, Table A.1.

Management practices are proxied by dummies for the application of both chemical inputs (fertilizer[5] and herbicides) and manual techniques, such as manual weeding, pruning, the removal of diseased fruits and the frequency of harvests. We also have information on participation in the GERNAS Pro Kakao program and include a corresponding dummy in some regressions without implying that this dummy will be able to capture causal program impacts.

We control for tree age by adding cocoa tree age and its squared term. Moreover, we include a dummy for pests, mainly the cocoa pod borer and the black pod disease. We further account for wealth (assets), education and migrant status as household characteristics.

We estimate a log-linear model[6] and some explanatory variables (agricultural area, expenditure on inputs and households' assets) are transformed to their natural logarithm to comply with the assumption of normal distribution, mitigate the problem of heteroskedasticity, and to make the model less sensitive to outliers. The estimated coefficient can thus be interpreted as (semi-)elasticities.

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[5] For our sample, only about one quarter of farmers applies fertilizer.

[6] Using the log value of yield removes observations with zero yields (e.g. during the initial phase of cocoa cultivation) from the estimation. As a robustness check, we also include observations with zero yields into the regression by adding 1 to each observation before transforming into logs. Results are similar and displayed in Appendix A.2.

The model potentially suffers from endogeneity, in particular without household fixed-effects. The OLS estimates of the effects of management practices are likely to be affected by omitted variable bias, as it is plausible that they are related to them same – unobserved – farmer ability as cocoa yields. To mitigate reverse causality of wealth, which might be determined by cocoa yields giving the farmer financial capacity to engage in input-intensive activities, we use lagged values of assets.

Table 4 shows the results of our analysis of yields. Columns (1) to (5) present the results of the pooled OLS model with time effects. Our baseline model (column 1) regresses yield on the main plot conditions as well as labor input. The coefficient of cocoa area is statistically significant and indicates that a 1 percent increase in total cocoa area under cultivation is on average associated with a 0.18 to 0.32 percent decrease in yields. This result indicates that larger cocoa plantations of smallholders are less intensively managed (for example, by intercropping with other plants). As expected, the estimated coefficient for tree age is significantly positive while the estimate for its squared term is negative. This reflects the yield curve for cocoa with first increasing and then decreasing yields and a turning point at about 16 to 19 years in our estimation. Labor input as measured by expenditures for hired workers is also associated with higher yields; the number of family members working on the plot does not seem to play a role though. Column 2 adds variables on management practices and we find input-intensive as well as labor-intensive activities to be an essential means to achieve high yields. The yield elasticity of fertilizer expenditure is 0.02. Similarly, the application of herbicides is positive and significant. Furthermore, manual practices seem to be an important ingredient for successful cocoa cultivation. A striking example is that farmers who prune their cocoa trees on average achieve 1.5 times the yield than those refraining from doing it (referring to column 2). Also removing diseased cocoa pods is essential, whereas controlling the growth of weeds by hand does not make a difference (only statistically significant in column 5).

Results on household characteristics (added in column 3) are mixed. Financial conditions of farm households – as measured by the ownership of assets – are statistically significant and positively correlated with yield. In other specifications, we use lagged values of assets to avoid reverse causality and the effect is no longer significant. The dummy on migration status is significantly negative (equals 1 in case of a local farmer) and hence indicates that migrants are more successful in cocoa cultivation than the local population. We further control for education of the household head and find the completion of primary and tertiary education to be positively correlated with cocoa yield.

Column (4) adds a pest dummy which is available for observations in 2006 and 2013. As expected, we find a negative effect which is insignificant though. However, we are hesitant to take this insignificant result at face value because pests are endogenous to a number of other regressors, in particular to management practices. Instead, we below investigate the correlates of crop failure to shed more light on the effects of pests.

Column (5) controls for the frequency of harvests and participation in the national cocoa program GERNAS that, among other things, trains farmers on cocoa cultivation (data is only available for 2013). Productivity remains unaffected by harvest frequency but there is evidence of a strong impact of GERNAS: Farmers that participate in the GERNAS program achieve on average 60 percent higher yields.[7]

Column (6) shows the findings of the long-term analysis based on the FE model.[8] The FE model is preferable to OLS as it takes the panel structure into account and controls for time-invariant heterogeneity across farm households (γ_i) which may bias estimation results.

Insert Table 4 here.

The FE model confirms our finding that both chemical (application of fertilizer)

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[7] This result is likely to suffer from endogeneity given the self-selection into the GERNAS program.

[8] An alternative panel data method is the random effects model. Performing the (robust) Hausman tests, however, allows us to reject the null hypothesis of exogeneity of explanatory variables with the time and household fixed effects at the 1 % level of significance for our baseline model and hence confirms our choice for the FE model specification.

as well as labor inputs (pruning, removal of diseased fruits) have a strong positive impact on yields. To sum up, cocoa yields mainly depend on proper management practices which include both the application of chemical inputs and manual strategies. The farmers' choice of management practices hence can explain a large share of the observed heterogeneity among our sample. Following a strategy of agricultural intensification (heavy use of fertilizer as well as application of herbicides) helps to increase yields. Also plot maintenance practices (especially pruning and the removal of diseased pods) have a great potential to considerably increase yields. These management practices appear to primarily affect yields in a direct way and rather not through preventing disease infestations.

While the FE model addresses endogeneity arising from household-specific time-invariant omitted variables, there might still be endogeneity originating from time-varying unobserved effects if correlated with the explanatory variables. To handle this problem of endogeneity, we adopt an Instrumental Variable (IV) approach to estimate Equation (1). The various management practices – our main explanatory variables – are instrumented with the average management practice in the village (excluding the specific farmer), the rationale being that farmers' management practices are influenced by those of their neighbors.[9] Applying this

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[9] This correlation is likely in a region where cocoa was only introduced in the early 2000s, whereas the neighbors' management practices should not have a direct effect on the farmer's yield.

IV approach yields very similar results and confirms that management practices have a strong impact on cocoa yields (see Table A.3 in the appendix).

To further explore the heterogeneity of production we apply a quantile regression, i.e. an approach that allows the parameters in Equation (1) to vary across different quantiles of cocoa yields (here the 10th, 25th, 50th, 75th and 90th quantile). The Breusch-Pagan test for heteroskedasticity rejects the null hypothesis of homoskedasticity and hence rules out that heteroskedastic error are driving our results.

Insert Table 5 here.

Table 5 shows the estimation results for our main covariates. It becomes apparent that yields of less productive and more productive farmers are determined by different factors. We find coefficients on plot conditions, management practices as well as household characteristics to vary across quantiles and to differ from the OLS model. The pseudo R² which varies between 0.25 and 0.28, however, indicates that the quantile regression model explains yield more or less equally well at different parts of the distribution.

With regard to plot conditions, the coefficients on plantation age are very instructive. They reveal that the shape of the cocoa yield curve varies markedly across quantiles. In contrast to the successful farmers, the productivity of low performers has a much steeper rise in the beginning, reaches the turning point at an earlier stage (e.g. at a tree age of 13 years for the 10th quantile compared to 17 years for the 90th quantile) and records a steeper downturn afterwards.

Moreover, the quantile regression results suggest that low and high performers have varying degrees of success with regard to management strategies.

At the lower tail of the yield distribution (10th quantile), farmers` agricultural practices do not have an effect on yield at all. Only the dummy on migrant status has a significant impact showing that being local has a strong negative effect on yield for the low performers. The low- to medium-performers (25th and 50th quantile) successfully rely on labor-intensive strategies (pruning and removal of diseased fruit, hired labor) to increase their yields. The effective application of fertilizers at the 50th and 75th quantile suggests that a well-managed intensification strategy could also help the lower quantiles to increase their yields. The high performers' (75th and 90th quantile) labor input (hiring labor and plot maintenance practices such as pruning and removal of diseased fruit) has also a positive effect, though with a slightly lower magnitude compared to the low- to medium-performers. To sum up, the quantile regression reveals that heterogeneity in yield among cocoa farmers illustrates the importance of both the choice of management practices and their effective implementation for the observed productivity heterogeneity of farmers.

In a final exercise of our empirical analyses, we examine the incidence and determinants of crop failures, which may be a threat to sustainable income gains of cocoa farmers. In line with the abovementioned reports on problems in Indonesia's cocoa sector ate large we observe a sharp increase in crop failures in our sample (see Table 6): In 2006, 9 percent of cocoa farmer report on crop failure for the last 5 years. This share increases to 44 percent alone for the year 2013. These losses are mostly due to pests and diseases, which explain 96 percent of all crop failures in 2006 and 78 percent in 2013 (other reasons are drought, flood or other weather phenomena). Hence in 2013, about one third of farmers is affected by pests and diseases. The reported pests and diseases are mainly the black pod disease and – to a slightly lesser extent – the cocoa pod borer.

Insert Table 6 here.

The incidence and intensity of crop failure increase both across tree age groups within the respective year as well as over time. To explore this trend further, we run an auxiliary regression that relates crop failure, management practices and agricultural shocks (see Table 7). We first regress crop failure on basic plot conditions and management practices (column 1), then add household characteristics (column 2), and finally the pest dummy (column 3). We measure crop failure by the percentage of regular yield lost, due to natural disasters (droughts, storms) or infestations with pest and diseases. Results are available only for 2006 and 2013, for which data on agricultural shocks is available.

As expected, proper management practices that are related to disease and pest management such as the application of herbicides, manual weeding and the removal of diseased pods are associated with lower yield losses. The same is true for harvest frequencies: Harvesting the cocoa trees more than once per month decreases the magnitude of yield loss.

Insert Table 7 here.

Additionally controlling for household characteristics (column 2) does not affect the estimated coefficients on the management practice proxies, which reinforces that we are actually observing an effect of those practices rather than the effect of some unobserved farmer ability that would be correlated with them. We find further evidence that especially the production of local farmers is affected by pests as the migrant status dummy is highly significant and positive. When we add a pest dummy (column 3) we can see that pests indeed explain the largest proportion of the variance in crop failures, as R-squared increases from 0.245 to 0.554. The effect is large: If a pest occurs, yield is on average diminished by 30 percent. The coefficients on management practices, in particular the use of herbicides, weeding, and removal of diseased pods, are smaller when the pest dummy is included. In other words, the omission of the pest dummy induced an upward bias of the mitigating effect of these practices in the first two specifications of Table 7. This indicates that a major transmission channel of better management practices on yields runs through the prevention and mitigation of pests. In addition, there is a significantly positive time trend in crop failures indicating that crop failures become more frequent in the region. In contrast to productivity, the magnitude of yield loss is largely unrelated to cocoa tree age and plantation size (when controlled for management practices). Further, the use of hired labor is significantly raising crop losses, but turns insignificant when including the pest dummy. This might indicate that farmers count on labor in the event of a crop failure, especially for pesticide spraying. Also the migrant status dummy gets insignificant in column (3), suggesting that the yield loss of locals, and probably lower yields in general, is partly due to pest infestations.

VII. Heterogeneity in cocoa yields and poverty outcomes

To connect our findings, we explore in a final step how productivity heterogeneity and the associated management practices are linked to long-term poverty reduction among cocoa farming households in the LLR. To proxy good management practices of cocoa plantations, we draw on three key determinants of cocoa productivity derived from the OLS and FE model above. First, we include the practice of tree pruning, which is highly positively correlated with cocoa yield and hence crucial for farmers' successful management of cocoa trees. Second, we consider the regular removal of diseased fruits as a key method to reduce the susceptibility to pests, especially the cocoa pod borer and the black pod disease. Third, we use the application of fertilizer, herbicides or both as proxy for advanced management practices with chemical inputs. Accordingly, to be classified as a cocoa farmer with good management practices, a farmer has to prune his cocoa trees, has to remove diseased fruits from his trees and has to apply any chemical input. Applying these criteria, we separate our sample into well-managing and not-well managing farmers, resulting in 33 farmers with good management practices in 2001, 82 in 2006 and 131 farmers in 2013 (see Table 8). Management practices on average thus improve considerably over time.

Insert Table 8 here.

We combine this information with the respective poverty status of farmers' households and illustrate in a next step all transitions in both farmers' management quality and income status over the total sample period. To this end, Table 9 shows all transitions of cocoa farmers between 2001, 2006 and 2013.[10]

Insert Table 9 here.

The results indicate that initially poor households can benefit from applying better management practices (23.4 percent of all initially poor and not-well managing farmers), but that a transition out of poverty is also possible without doing so (a third of all initially poor and not-well managing farmers). Staying poor is associated with continued worse farm management and, while well-

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[10] In total, 275 farmers could be interviewed concerning their management practices in 2001, 2006 and/or 2013. Of those 275 households, 141 could be interviewed three times (i.e. two transitions), 86 could be interviewed twice (i.e. one transition) and 48 could be interviewed once (i.e. no transition), adding up to 643 observations and 368 transitions.

managing farm households find it much easier to escape poverty (59.3% percent from the initially poor, well- managing households).

Looking at non-poor households confirms an important role for farming practices. The majority of cases (N=54 and 72 %) of initially non-poor, well-managing households are households continuing their good management practices and maintain non-poor income levels. The latter holds also for the 43 farmers that improve management practices. And while no initially non-poor farmer who manages well falls into poverty, this happens to 37 households without good management practices.

VIII. Conclusion

The present study shows that cash crop farming can be associated with strong and sustainable poverty reduction. In our study region in Central Sulawesi and over the analyzed time horizon of more than 10 years, cocoa farmers fare considerably better than non-cocoa farmers and the welfare gains are less volatile than might be anticipated in light of the problems, in particular the occurrence of pests, faced by the Indonesian cocoa sector at large in the period under consideration.

The large increases in cocoa income can mainly be attributed to increasing cocoa yields. However, yield gaps remain large and are increasingly heterogeneous. We can trace back this productivity heterogeneity to farm management practices that include both the application of chemical inputs and manual practices. The farmers' choice of management practices hence can explain a large share of the observed productivity heterogeneity in our sample. These management practices seem to have a direct positive effect on yields as well as indirect positive effect through the prevention and mitigation of crop failures, which tend to become increasingly common because of more frequent pest infestations in the region.

Taken together, increased cocoa yields and the importance of management techniques suggest that the improvement of management practices can be linked to improved livelihoods. And indeed, we can empirically establish this Link: We can show that better management practices facilitate the transition out of poverty and shields against income losses.

In light of the still gasping yield gaps of cocoa farmers in the region, our findings are good news as they show the potential of improving agricultural productivity to raise living standards. However, poverty persistence and the persistence of bad management among a substantial fraction of farmers may imply that these farmers may be much harder to reach. Finally, the increasing incidence of pests, especially the cocoa pod borer and the black pod disease, might require more focused interventions. While intensification strategies have in the past helped cocoa farmers to considerably increase yields, they may, together with aging plantations, aggravate the incidence of pests and diseases. Thus, management skills may have to improve beyond the simple intensification techniques and replanting will have to accelerate. This may be required to sustain the livelihood improvements that the cocoa sector has brought to many smallholders in Sulawesi.

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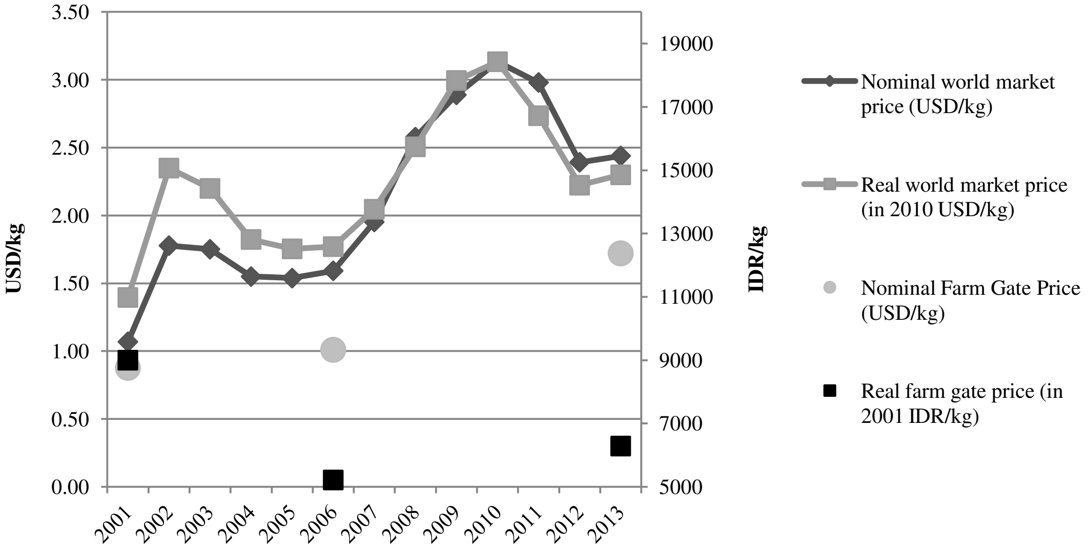
Figures

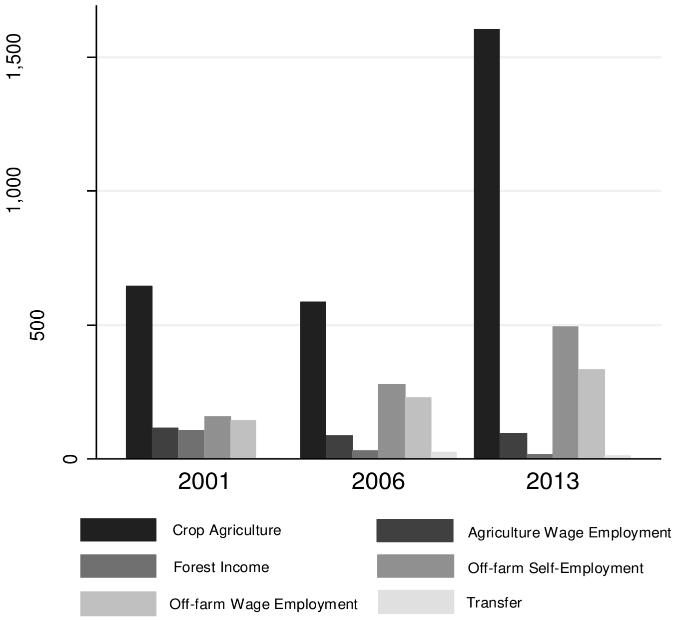
Figure 1: World market and farm gate prices for cocoa (in USD/kg and IDR/kg)



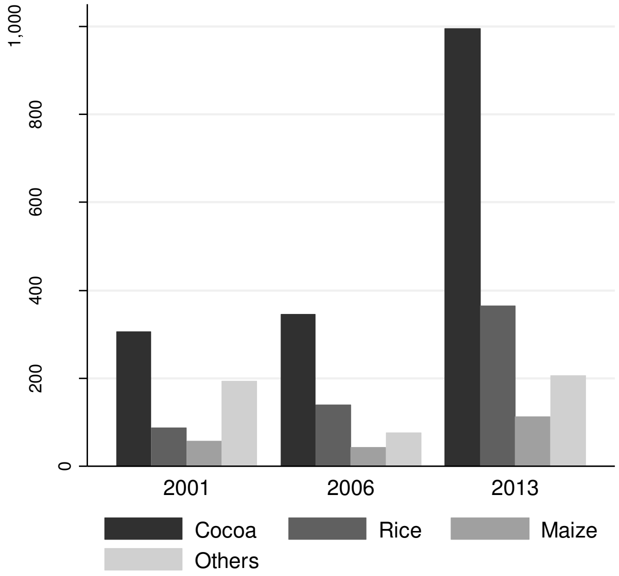
Note: Nominal farm gate prices are calculated as the median value of village prices. Village prices on cocoa are in turn derived as median values from the household-level output prices for cocoa. Real farm gate prices are in 2001 IDR prices, based on inflation data for Palu from BPS Statistics Indonesia (2016a). Nominal and real world market prices are drawn from The World Bank (2016b).
Source: The World Bank (2016b) and authors' calculation and graphical representation based on STORMA and EFForTS data.

Figure 2: Mean per Capita Income by Sector of Employment and Main Cultivated Crops, 2001-2013

A) Sector of Employment

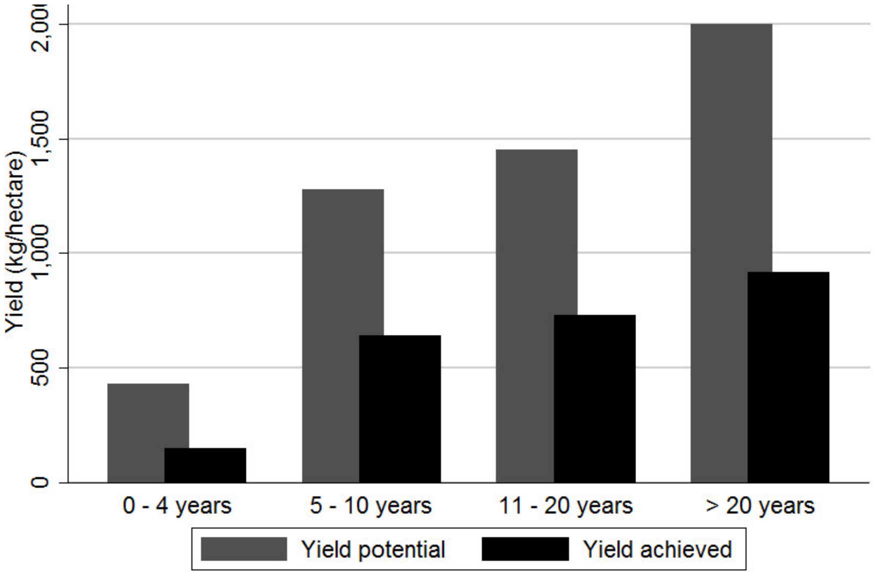


B) Main Cultivated Crops



Notes: Monetary values are real Indonesian Rupiahs with base year 2001, using the provincial Consumer Price Index (CPI) for Palu provided by BPS Statistics Indonesia (2016a). Incomes are yearly. The data represent the mean of all per capita household income per income source. To calculate the per capita household income, households' income (per source) is divided by the respective and idiosyncratic household size. The mean values consider also income sources with zero income.
Source: Authors' calculation and graphical representation based on STORMA and EFForTS data.

Figure 3: Yield gaps per tree age group, 2001-2013



Source: Authors’ calculation and graphical representation based on STORMA and EFForTS Data.

Tables

Table 1: Comparison of Poverty Measures for USD 1/Day PPP Poverty Line from 2001-2013

	Poverty Headcount			**Poverty Gap**			**Observations**		
	2001	2006	2013	2001	2006	2013	2001	2006	2013
All households	62.33	53.60	32.61	36.30	23.38	17.66	300	338	322
Cocoa farmers	54.55	46.35	24.36	31.30	19.30	13.18	176	233	234
- with at least 1/3 off-farm income	33.33	21.15	13.89	10.37	3.90	7.64	30	52	36
Non-cocoa farmers	73.39	69.52	54.55	43.43	32.56	29.55	124	105	88
- with at least 1/3 off-farm income	54.55	52.63	35.71	23.59	23.37	16.54	33	38	42

Notes: Currency conversion based on World Bank PPP (purchasing power parity) conversion factor for private consumption (LCU per international $). Households with a cocoa plantation of at least 0.25 hectare are classified as cocoa farmers.
Source: Authors' calculation based on STORMA and EFForTS data.

Table 2: Transition Matrix for usd1/day pp poverty lines for cocoa farmers (C) and non-cocoa-farmers (NC), 2001-2013

A)

	2006	Poor (USD 1/day)		Non-Poor		
2001		C	NC	C	NC	∑
Poor **(USD 1/day)**	C	43.6 [41]	7.5 [7]	45.7 [43]	3.2 [3]	100 [94]
	NC	20.0 [18]	48.9 [44]	15.6 [14]	15.6 [14]	100 [90]
Non-Poor	C	33.3 [26]	1.3 [1]	60.3 [47]	5.1 [4]	100 [78]
	NC	21.2 [7]	33.3 [11]	21.2 [7]	24.2 [8]	100 [33]
	∑	31.2 [92]	21.4 [63]	37.6 [111]	9.8 [29]	100 [295]

B)

	2013	Poor (USD 1/day)		Non-Poor		
2006		C	NC	C	NC	∑
Poor **(USD 1/day)**	C	28.8 [30]	8.7 [9]	58.7 [61]	3.8 [4]	100 [104]
	NC	15.9 [11]	39.1 [27]	15.9 [11]	29.0 [20]	100 [69]
Non-Poor	C	12.6 [15]	1.7 [2]	79.8 [95]	5.9 [7]	100 [119]
	NC	4.0 [1]	40.0 [10]	24.0 [6]	32.0 [8]	100 [25]
	∑	18.0 [57]	15.1 [48]	54.6 [173]	12.3 [39]	100 [317]

Notes: Currency conversion based on World Bank PPP conversion factor for private consumption (LCU per international $). Values are rounded. Numbers of households are in parentheses. Since most households in our region have adopted cocoa during the first period, we assume as cocoa farmers all households with at least two observations and with a cocoa plantation of at least 0.25 hectare.
Source: Authors' calculation based on STORMA and EFForTS data.

Table 3: Measures of variance for cocoa income and its components for cocoa farmers, 2001-2013

	2001	**2006**	**2013**
		mean (standard deviation)	
P.c. household cocoa income	513,551 (1,255,471)	496,847 (603,385)	1,353,738 (1,875,858)
Crop Area (are)	1.4 (1.3)	1.4 (1.2)	1.5 (1.7)
Yield (kg/are)	211.6 (328.9)	349.0 (273.0)	815.6 (822.3)
Price (IDR/kg)	8,527.0 (1,206.4)	5,266.9 (423.7)	6,446.5 (279.6)

Note: Households with an cocoa plantation of at least 0.25 hectare are included. Monetary values are real IDR with base year 2001, using the provincial CPI for Palu provided by BPS Statistics Indonesia (2016a). Local land units are measured in are. One are is equal to 100 m^2. Prices are village medians of farm gate prices.

Source: Authors' calculation based on STORMA and EFForTS data.

Table 4: Determinants of cocoa productivity (Pooled OLS and FE Model), 2001-2013

VARIABLES	(1) Cocoa yield (log)	(2) Cocoa yield (log)	(3) Cocoa yield (log)	(4) Cocoa yield (log)	(5) Cocoa yield (log)	(6) Cocoa yield (log)
Estimation	OLS	OLS	OLS	OLS	OLS	FE
Cocoa area (log)	-0.175***	-0.211***	-0.267***	-0.296***	-0.320***	-0.460***
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tree age	0.221***	0.195***	0.183***	0.118***	0.099**	0.164***
	(0.000)	(0.000)	(0.000)	(0.002)	(0.015)	(0.000)
Tree age^2	-0.006***	-0.006***	-0.005***	-0.003***	-0.003**	-0.005***
	(0.000)	(0.000)	(0.000)	(0.006)	(0.016)	(0.000)
Labor exp. (log)	0.049***	0.035***	0.032***	0.020*	0.015	0.017
	(0.000)	(0.000)	(0.000)	(0.052)	(0.414)	(0.139)
Family workers (#)	-0.017	-0.016	-0.014	0.018	0.028	0.011
	(0.582)	(0.571)	(0.635)	(0.608)	(0.646)	(0.804)
Fertilizer exp. (log)		0.018**	0.007	0.014	0.007	0.031**
		(0.046)	(0.463)	(0.148)	(0.605)	(0.034)
Use of herbicides		0.323*	0.305*	0.553**	1.146***	0.330
		(0.081)	(0.100)	(0.015)	(0.003)	(0.120)
Manual weeding		0.046	0.086	0.212	0.775**	0.084
		(0.795)	(0.626)	(0.331)	(0.035)	(0.688)
Pruning		0.445***	0.405**	0.417**	0.189	0.734***
		(0.007)	(0.022)	(0.044)	(0.432)	(0.000)
Removing pods		0.661***	0.667***	0.617***	0.486**	0.383*
		(0.000)	(0.000)	(0.000)	(0.048)	(0.078)
Migrant status			-0.273***	-0.274***	-0.525***	
			(0.004)	(0.008)	(0.003)	
Primary edu.			0.143	0.234	0.656**	
			(0.258)	(0.141)	(0.025)	
Secondary edu.			-0.187	-0.123	0.126	
			(0.271)	(0.576)	(0.715)	
Tertiary edu			-0.002	0.275	0.585**	
			(0.988)	(0.104)	(0.046)	
Assets (log)			0.062**			
			(0.018)			
Lagged assets (log)				0.035	0.023	
				(0.221)	(0.558)	
Pest				-0.091	-0.019	
				(0.423)	(0.892)	
GERNAS					0.598***	
					(0.001)	
Harvest frequency					0.152	
					(0.255)	
Year = 2006	0.081	0.065	0.148			0.265*
	(0.508)	(0.584)	(0.216)			(0.066)
Year = 2013	0.537***	0.481***	0.590***	0.445***		0.771***
	(0.001)	(0.001)	(0.000)	(0.000)		(0.000)
Constant	4.273***	3.290***	3.050***	3.524***	3.615***	3.222***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	554	554	551	368	209	554
R-squared	0.312	0.384	0.405	0.355	0.306	0.472
Adj. R-squared	0.303	0.370	0.386	0.324	0.241	
Number of id						257
Within R-squared						0.472
Between R-squared						0.151

Note: Pval in parentheses, *** p<0.01, ** p<0.05, * p<0.1, year dummies included, cluster-robust standard errors. Households with a cocoa plantation of at least 0.25 hectare are included.

Source: Authors' calculation based on STORMA and EFForTS data.

Table 5: Quantile Regression of determinants of yields (Pooled OLS), 2001-2013

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cocoa yield (log)	Cocoa yield (log)	Cocoa yield (log)	Cocoa yield (log)	Cocoa yield (log)	Cocoa yield (log)
Estimation	OLS	Q (10th)	Q (25th)	Q (50th)	Q (75th)	Q (90th)
Cocoa area (log)	-0.240***	-0.276*	-0.193*	-0.272***	-0.215***	-0.290***
	(0.000)	(0.059)	(0.064)	(0.000)	(0.000)	(0.000)
Tree age	0.189***	0.397***	0.252***	0.172***	0.129***	0.101**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.011)
Tree age²	-0.006***	-0.015***	-0.009***	-0.005***	-0.004***	-0.003*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.075)
Labor exp. (log)	0.035***	0.040	0.041**	0.034***	0.024**	0.022*
	(0.000)	(0.147)	(0.024)	(0.000)	(0.015)	(0.092)
Family workers (#)	-0.012	-0.037	-0.010	-0.008	-0.023	-0.001
	(0.679)	(0.637)	(0.858)	(0.706)	(0.446)	(0.983)
Fertilizer exp. (log)	0.010	0.014	0.008	0.012**	0.016*	0.011
	(0.252)	(0.565)	(0.611)	(0.042)	(0.075)	(0.345)
Use of herbicides	0.348*	0.233	0.438	0.219*	0.040	0.076
	(0.055)	(0.481)	(0.202)	(0.092)	(0.824)	(0.722)
Manual weeding	0.096	0.094	0.269	-0.027	-0.123	-0.076
	(0.578)	(0.762)	(0.416)	(0.828)	(0.472)	(0.721)
Pruning	0.428**	0.351	0.554*	0.474***	0.456***	0.346
	(0.014)	(0.203)	(0.081)	(0.000)	(0.006)	(0.136)
Removing pods	0.662***	0.421	0.666***	0.786***	0.569***	0.397**
	(0.000)	(0.201)	(0.004)	(0.000)	(0.000)	(0.022)
Migrant status	-0.300***	-0.696***	-0.442**	-0.142**	-0.109	-0.189*
	(0.001)	(0.010)	(0.013)	(0.034)	(0.254)	(0.088)
Primary edu.	0.158	0.302	0.095	0.057	0.074	0.235
	(0.213)	(0.439)	(0.720)	(0.561)	(0.599)	(0.164)
Secondary edu.	-0.150	-0.130	-0.412	-0.350***	0.092	0.315
	(0.377)	(0.777)	(0.200)	(0.003)	(0.587)	(0.151)
Tertiary edu.	0.089	0.287	0.015	0.083	0.110	0.283
	(0.552)	(0.521)	(0.959)	(0.450)	(0.477)	(0.121)
Year = 2006	0.090	0.110	0.201	0.179**	0.078	-0.245
	(0.451)	(0.723)	(0.380)	(0.029)	(0.513)	(0.135)
Year = 2013	0.559***	0.333	0.624**	0.656***	0.593***	0.455**
	(0.000)	(0.372)	(0.024)	(0.000)	(0.000)	(0.011)
Constant	3.413***	1.941***	2.533***	3.517***	4.540***	5.383***
	(0.000)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	554	554	554	554	554	554
R-squared	0.400					
Adj. R-squared	0.382					
Pseudo R-squared		0.273	0.267	0.245	0.227	0.253

Note: Pval in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$, year dummies included. Households with a cocoa plantation of at least 0.25 hectare are included.

Source: Authors' calculation based on STORMA and EFForTS data.

Table 6: Cocoa tree age: yield and crop failures, 2006-2013

	2006				2013			
Tree age	Cases	Yield (kg/ha.)	Crop failure	Lost yield (%)	Cases	Yield (kg/ha.)	Crop failure	Lost yield (%)
Years	*n*	*mean (sd)*	*N*	*mean (sd)*	*n*	*mean (sd)*	*n*	*mean (sd)*
0 – 4	89	154.3 (200.2)	2	0.6 (3.7)	22	236.9 (386.3)	0	0
5 – 10	115	462.0 (240.9)	13	3.6 (12.2)	110	905.0 (967.8)	52	18.5 (23.8)
11 – 20	28	497.9 (247.8)	7	8.25 (16.1)	84	823.8 (656.1)	40	18.1 (24.0)
> 20	1	513.3 (-)	0	0	18	938.0 (689.9)	10	28.0 (31.6)
0 - 36	233	349.0 (273.0)	22	3.0 (10.7)	234	815.6 (822.3)	102	17.4 (24.1)

Note: Households with a cocoa plantation of at least 0.25 hectare are included. Cases where trees have been rehabilitated or rejuvenated (e.g. method of "Sambung Samping") were dropped as they are no longer representative for tree age descriptives (in total 13 cases in 2013).

Source: Authors' calculation based on STORMA and EFForTS.

Table 7: Determinants of crop failure (Pooled OLS), 2001-2013

VARIABLES	(1) Crop failure	(2) Crop failure	(3) Crop failure
Cocoa area (log)	-0.802	-0.611	-0.717
	(0.556)	(0.674)	(0.514)
Tree age	0.873	0.991*	0.190
	(0.109)	(0.054)	(0.630)
Tree age²	-0.020	-0.022	0.005
	(0.269)	(0.215)	(0.718)
Labor exp. (log)	0.411**	0.413**	-0.017
	(0.015)	(0.014)	(0.895)
Family workers (#)	1.034	0.923	1.117**
	(0.123)	(0.173)	(0.020)
Fertilizer exp. (log)	-0.168	-0.061	-0.217
	(0.429)	(0.762)	(0.146)
Use of herbicides	-24.279***	-25.783***	-14.308***
	(0.000)	(0.000)	(0.004)
Manual weeding	-21.173***	-22.920***	-13.735***
	(0.000)	(0.000)	(0.006)
Pruning	3.363	1.032	-2.981
	(0.608)	(0.884)	(0.646)
Removing pods	-6.550**	-5.475**	-4.438*
	(0.023)	(0.048)	(0.057)
Harvest frequency	-3.721*	-3.463*	-2.519
	(0.066)	(0.084)	(0.124)
Migrant status		3.788*	0.115
		(0.053)	(0.939)
Primary edu.		-3.212	-0.336
		(0.144)	(0.838)
Secondary edu.		2.589	4.832*
		(0.426)	(0.075)
Tertiary edu.		-3.035	2.800
		(0.259)	(0.196)
Lagged assets (log)		-0.527	-0.081
		(0.296)	(0.824)
Pest			29.974***
			(0.000)
Year = 2013	14.469***	14.045***	6.734***
	(0.000)	(0.000)	(0.000)
Constant	21.541**	26.320***	17.445**
	(0.017)	(0.010)	(0.027)
Observations	430	413	413
R-squared	0.224	0.245	0.554

Note: Pval in parentheses, *** p<0.01, ** p<0.05, * p<0.1, cluster-robust standard errors. Households with a cocoa plantation of at least 0.25 hectare are included.

Source: Authors' calculation based on STORMA and EFForTS data.

Table 8: Numbers of well managing and not-well managing cocoa farmers

	2001	2006	2013
No. of well managing farmers	33	82	131
No. of not-well managing farmers	143	151	103
No. of all farmers	176	233	234

Note: Households with a cocoa plantation of at least 0.25 hectare are classified as cocoa farmers.
Source: Authors' calculation based on STORMA and EFForTS data.

Table 9: Transition Matrix for usd 1/day ppp poverty lines for cocoa farmers with well and not-well agricultural practices, 2001-2013, total Transition cases

$\boldsymbol{TRANS_{i,t+n}}$ $with$ $\boldsymbol{n} = \{1; 2\}$ $\boldsymbol{TRANS_{i,t}}$		**Poor (USD 1/day)**		**Non-Poor**		
		WELL	NOT WELL	WELL	NOT WELL	Σ
Poor (USD 1/day)	WELL	3.7 [1]	14.8 [4]	59.3 [16]	22.2 [6]	100 [27]
	NOT WELL	10.4 [16]	33.1 [51]	23.4 [36]	33.1 [51]	100 [154]
Non-Poor	WELL	13.3 [10]	0.0 [0]	72.0 [54]	14.7 [11]	100 [75]
	NOT WELL	4,5 [5]	24.1 [27]	38.4 [43]	33.0 [37]	100 [112]
	Σ	8.7 [32]	22.3 [82]	40.5 [149]	28.5 [105]	100 [368]

Notes: Currency conversion based on World Bank PPP conversion factor for private consumption (LCU per international $). Households with a cocoa plantation of at least 0.25 hectare are classified as cocoa farmers. Transitions are considered for at least one change.

Source: Authors' calculation based on STORMA and EFForTS data.

Appendix

Table A.1: Summary statistics for variables used in regression model, 2001-2013

Variable	Unit	Year	Average	Min	Max	Median	Std. Dev.	n
Dependent variables								
Cocoa yield	kg/hectare	2001	211.6	0.0	2933.3	93.0	328.9	176
		2006	349.0	0.0	1140.0	300.0	273.0	233
		2013	815.6	0.0	4800.0	592.9	822.3	234
Crop Failure	% of yield lost	-	-	-	-	-	-	-
		2006	3.0	0.0	75.0	0.0	10.7	233
		2013	17.4	0.0	90.0	0.0	24.1	234
Basic agricultural parameters								
Cocoa area	hectare	2001	1.4	0.25	8.3	1.0	1.3	176
		2006	1.4	0.25	8.0	1.0	1.2	233
		2013	1.5	0.25	15.0	1.0	1.6	234
Tree age	years	2001	3.8	1.0	20.0	3.0	3.2	166
		2006	6.3	0.3	22.0	5.0	4.1	233
		2013	11.2	0.3	36.0	10.0	6.3	234
Labor exp.	000 IDR/ha	2001	25.3	0	500.0	0	76.9	176
		2006	39.0	0	966.7	0	111.9	233
		2013	52.2	0	1982.3	0	250.1	234
No. of family workers	number	2001	3.0	0	8	3	1.6	176
		2006	2.5	0	7	2	1.3	233
		2013	1.9	0	6	2	1.2	233
Management practices								
Fertilizer exp.	000 IDR/ha	2001	29.5	0	710	0	110.5	176
		2006	17.5	0	433.7	0	60	233
		2013	69.3	0	1397.2	0	170.7	234
Use of herbicides	dummy	2001	0.1	0	1	0	0.3	176
	0=no	2006	0.4	0	1	0	0.5	233
	1=yes	2013	0.5	0	1	0	0.5	234
Manual weeding	dummy	2001	0.6	0	1	1	0.5	176
	0=no	2006	0.5	0	1	1	0.5	233
	1=yes	2013	0.5	0	1	1	0.5	234
Pruning	dummy	2001	0.7	0	1	1	0.5	176
	0=no	2006	0.9	0	1	1	0.3	233
	1=yes	2013	0.9	0	1	1	0.3	234
Removing pods	dummy	2001	0.9	0	1	1	0.3	176
	0=no	2006	0.8	0	1	1	0.3	233
	1=yes	2013	0.9	0	1	1	0.4	234
Harvest freq.	dummy	-	-	-	-	-	-	-
	0=less than 2 times/month	2006	0.7	0	1	1	0.5	210
	1=more than 2 times/month	2013	0.4	0	1	0	0.5	221
GERNAS	dummy	-	-	-	-	-	-	-
	0=no	-	-	-	-	-	-	-
	1=yes	2013	0.1	0	1	0	0.3	234
Pest incidence								
Pest	dummy	-	-	-	-	-	-	-
	0=no	2006	0.1	0	1	0	0.3	233
	1=yes	2013	0.3	0	1	0	0.5	234
Household characteristics								
Migrant status	dummy	2001	0.7	0	1	1	0.5	176
	0=migrant	2006	0.7	0	1	1	0.5	233
	1=local	2013	0.8	0	1	1	0.4	233
Primary Edu.	dummy	2001	0.6	0	1	1	0.5	176
	0=no	2006	0.5	0	1	1	0.5	233
	1=yes	2013	0.6	0	1	1	0.5	233
Secondary Edu.	dummy	2001	0.2	0	1	0	0.4	176
	0=no	2006	0.1	0	1	0	0.3	233
	1=yes	2013	0.1	0	1	0	0.3	233
Tertiary Edu.	dummy	2001	0.2	0	1	0	0.4	176
	0=no	2006	0.2	0	1	0	0.4	233

	1=yes	2013	0.2	0	1	0	0.4	233
Assets	000 IDR	2001	4321.1	15.0	58050.0	1025.0	7775.1	175
		2006	3555.0	3.7	97473.6	68.1	9264.0	232
		2013	6820.0	3.1	331381.9	2698.4	24533.8	231

Source: Authors’ calculation based on STORMA and EFForTS data.

Table A.2: Robustness check: Inclusion of zero yields
Determinants of cocoa productivity (Pooled OLS and FE Model), 2001-2013

VARIABLES	(1) Cocoa yield (log)	(2) Cocoa yield (log)	(3) Cocoa yield (log)	(4) Cocoa yield (log)	(5) Cocoa yield (log)	(6) Cocoa yield (log)
Estimation	OLS	OLS	OLS	OLS	OLS	FE
Cocoa area (log)	0.020	-0.010	-0.053	-0.194**	-0.319***	-0.078
	(0.816)	(0.903)	(0.525)	(0.017)	(0.000)	(0.638)
Tree age	0.568***	0.458***	0.448***	0.238***	0.099**	0.370***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.014)	(0.000)
Tree age²	-0.017***	-0.014***	-0.013***	-0.007***	-0.003**	-0.012***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.016)	(0.000)
Labor exp. (log)	0.040***	0.016	0.015	0.025**	0.015	-0.010
	(0.006)	(0.228)	(0.255)	(0.029)	(0.413)	(0.557)
Family workers (#)	0.047	0.018	0.012	0.050	0.028	0.000
	(0.329)	(0.689)	(0.798)	(0.235)	(0.647)	(0.996)
Fertilizer exp. (log)		0.018	0.009	0.008	0.007	0.038**
		(0.107)	(0.457)	(0.476)	(0.605)	(0.043)
Use of herbicides		0.501*	0.477*	1.090***	1.143***	0.422
		(0.061)	(0.078)	(0.002)	(0.003)	(0.171)
Manual weeding		0.218	0.223	0.797**	0.773**	0.090
		(0.413)	(0.408)	(0.025)	(0.034)	(0.773)
Pruning		1.496***	1.489***	1.590***	0.190	1.490***
		(0.000)	(0.000)	(0.000)	(0.429)	(0.000)
Removing pods		0.958***	0.963***	0.810***	0.482**	0.767***
		(0.000)	(0.000)	(0.002)	(0.048)	(0.010)
Migrant status			-0.240*	-0.256*	-0.522***	
			(0.074)	(0.080)	(0.003)	
Primary edu.			-0.065	0.251	0.652**	
			(0.700)	(0.156)	(0.025)	
Secondary edu.			-0.403*	-0.140	0.125	
			(0.093)	(0.579)	(0.715)	
Tertiary edu.			-0.244	0.314*	0.582**	
			(0.235)	(0.098)	(0.046)	
Assets (log)			0.030			
			(0.400)			
Lagged assets (log)				0.000	0.023	
				(0.992)	(0.556)	
Pest				-0.004	-0.019	
				(0.974)	(0.888)	
GERNAS					0.596***	
					(0.001)	
Harvest frequency					0.151	
					(0.256)	
Year = 2006	0.527**	0.436**	0.452**			0.805***
	(0.011)	(0.024)	(0.023)			(0.000)
Year = 2013	0.530**	0.416*	0.497**	0.273*		0.918***
	(0.035)	(0.071)	(0.032)	(0.091)		(0.005)
Constant	1.700***	0.014	0.197	1.056*	3.627***	0.505
	(0.000)	(0.965)	(0.634)	(0.073)	(0.000)	(0.205)
Observations	632	632	628	452	208	632
R-squared	0.447	0.551	0.553	0.553	0.284	0.524
Adj. R-squared	0.440	0.542	0.540	0.536	0.216	
Number of id						273
Within R-squared						0.524
Between R-squared						0.538

Note: Pval in parentheses, *** p<0.01, ** p<0.05, * p<0.1, year dummies included, cluster-robust standard errors. Households with a cocoa plantation of at least 0.25 hectare are included. Zero yields are included by adding 1 to yield before transforming into log.

Source: Authors' calculation based on STORMA and EFForTS data.

Table A.3: Robustness check: Instrumental Variable Approach Determinants of cocoa productivity (2SLS and Maximum Likelihood), 2001-2013

VARIABLES	(1) Cocoa yield (log)	(2) Cocoa yield (log)	(3) Cocoa yield (log)	(4) Cocoa yield (log)	(5) Cocoa yield (log)	(6) Cocoa yield (log)
Estimation	OLS	IV-2SLS	IV-ML	IV-ML	IV-ML	IV-ML
Cocoa area (log)	-0.267***	-0.283***	-0.270***	-0.259***	-0.262***	-0.244***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tree age	0.183***	0.166***	0.185***	0.185***	0.183***	0.162***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tree age^2	-0.005***	-0.005***	-0.006***	-0.006***	-0.005***	-0.005***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Labor exp. (log)	0.032***	0.030***	0.028***	0.031***	0.032***	0.027***
	(0.000)	(0.002)	(0.005)	(0.002)	(0.001)	(0.010)
Family workers (#)	-0.014	-0.010	-0.012	-0.013	-0.016	-0.027
	(0.635)	(0.741)	(0.704)	(0.679)	(0.593)	(0.407)
Fertilizer exp. (log)	0.007	0.072**	0.005	0.007	0.010	0.005
	(0.463)	(0.042)	(0.584)	(0.467)	(0.316)	(0.610)
Use of herbicides	0.305*	0.253	0.968***	0.717	0.615*	0.260
	(0.100)	(0.184)	(0.006)	(0.368)	(0.082)	(0.200)
Manual weeding	0.086	0.081	0.645**	0.529	0.391	0.092
	(0.626)	(0.655)	(0.035)	(0.534)	(0.256)	(0.632)
Pruning	0.405**	0.308*	0.129	0.206	-0.203	0.295
	(0.022)	(0.091)	(0.542)	(0.617)	(0.737)	(0.113)
Removing pods	0.667***	0.641***	0.654***	0.668***	0.702***	1.630***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Migrant status	-0.273***	-0.120	-0.279***	-0.287***	-0.269***	-0.289***
	(0.004)	(0.315)	(0.006)	(0.006)	(0.008)	(0.006)
Primary edu.	0.143	0.164	0.150	0.148	0.163	0.167
	(0.258)	(0.228)	(0.309)	(0.313)	(0.275)	(0.277)
Secondary edu.	-0.187	-0.098	-0.191	-0.194	-0.188	-0.140
	(0.271)	(0.594)	(0.275)	(0.267)	(0.284)	(0.445)
Tertiary edu	-0.002	0.013	-0.014	-0.002	-0.015	0.006
	(0.988)	(0.934)	(0.932)	(0.992)	(0.930)	(0.973)
Assets (log)	0.062**	0.031	0.064***	0.062**	0.062**	0.065***
	(0.018)	(0.339)	(0.008)	(0.011)	(0.011)	(0.007)
Year = 2006	0.148	0.222*	0.076	0.118	0.205	0.332**
	(0.216)	(0.073)	(0.552)	(0.382)	(0.127)	(0.022)
Year = 2013	0.590***	0.579***	0.493***	0.545***	0.625***	0.753***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Constant	3.050***	3.168***	2.802***	2.857***	3.243***	2.314***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	551	551	551	551	551	551
Instrument relevance:						
- F-statistic	-	29.2	-	-	-	-
- correlation		0.43	0.36	0.14	0.21	0.19
Endogenous regressor	-	Fertilizer exp. (log)	Use of herbicides	Manual weeding	Pruning	Removing pods

Note: Pval in parentheses, *** p<0.01, ** p<0.05, * p<0.1, year dummies included, cluster-robust standard errors. Households with a cocoa plantation of at least 0.25 hectare are included.

Source: Authors’ calculation based on STORMA and EFForTS data.