ONLINE APPENDIX

Agricultural Productivity and Fertility: Evidence from the Oil Palm Boom in Indonesia

Esther Gehrke and Christoph Kubitza[†]

[†]Corresponding author: Christoph Kubitza, German Institute for Global and Area Studies (GIGA), Neuer Jungfernstieg 21, 20354 Hamburg, Germany. Email: christoph.kubitza@giga-hamburg.de. Esther Gehrke: Wageningen University and Research, Agricultural Economics and Rural Policy, Hollandse Weg 1, 6706KN Wageningen, The Netherlands. Email: esther.gehrke@wur.nl. Online Appendix can be found at http://jhr.uwpress.org/

Appendix A: Theoretical considerations

A.1. Oil palm expansion as increase in agricultural productivity

We consider each regency in Indonesia to behave like a small open economy, and to consist of two sectors: an agricultural sector and a non-agricultural sector. Agricultural goods can be traded (nationally or internationally), but production factors and the non-agricultural good are immobile.[1]

Agricultural production is governed by the following constant elasticity of substitution (CES) production function:

$$Q_a = A_N[(A_L L_a)^\rho + (A_T T_a)^\rho]^{1/\rho} \quad \text{(A.1)}$$

with Q_a being agricultural output, L_a aggregate agricultural labor, and T_a total agricultural land. A_N, A_L, and A_T are factor-neutral, labor-specific and land-specific productivity parameters, respectively. $\rho \leq 1$ is the complementarity parameter, and the elasticity of substitution $\sigma \in (0, \infty)$ is defined as $\sigma = 1/1 - \rho$.[2] Labor can move freely between the agricultural and the non-agricultural sector, and land is fixed initially. The non-agricultural good is produced exclusively with labor, *i.e.* $Q_n = A_n L_n$. Because we consider each regency to be a small open economy, and labor can move freely between both sectors, agricultural producers are price takers with respect to output prices and wages. They will thus choose input levels that equalize the marginal product of labor (MPL_a) to (real) wages:

$$\frac{w}{p_a} = MPL_a = A_N A_L^\rho \left[A_L^\rho + A_T^\rho \left(\frac{T_a}{L_a}\right)^\rho\right]^{1-\rho/\rho}. \quad \text{(A.2)}$$

Since our interest is in fertility decisions, we model the effect of oil palm on gender-specific labor demand explicitly. We adapt the framework of Acemoglu (2002) and characterize agricultural labor L_a as CES aggregate of female (F_a) and male (M_a) labor:

$$L_a = [(A_F F_a)^\varepsilon + (A_M M_a)^\varepsilon]^{1/\varepsilon}. \quad \text{(A.3)}$$

The fact that labor can move between sectors again implies that the (gender-specific) marginal product of labor MPL must equal wages. Specifically, one can write:

$$\frac{w_M}{w_F} = \left(\frac{A_M}{A_F}\right)^\varepsilon \left(\frac{M}{F}\right)^{-(1-\varepsilon)}. \quad \text{(A.4)}$$

We incorporate the fact that male labor productivity in oil palm production is higher than in the production in other crops while female labor productivity is the same across crops, by modelling the effect of the expansion of oil palm in the agricultural sector as an increase in A_M. Solving for F/M and differentiating with respect to A_M reveals that an increase in the productivity of male labor reduces the share of female workers in agriculture as long as $0 < \varepsilon < 1$, *i.e.* as long as male and female workers are substitutes in the production of the agricultural good.[3]

[1] The predictions of the model are the same as in a three-sector economy, where manufacturing goods can be traded, but not the service sector output.

[2] When $\sigma = \infty$, the two factors are perfect substitutes, and when $\sigma = 0$ the two factors are perfect complements. In line with Acemoglu (2002), we abstract from the share parameter for the sake of simplicity.

[3] Note that we do not need to make any assumption about the relative productivity of male and female workers, we just need to assume that there is no minimum of female workers needed for male workers to be productive and vice versa.

The effect of a change in A_M on overall demand for labor, then, depends on the complementarity between land and labor in overall agricultural production. Bustos et al. (2016) demonstrate that an increase in the productivity of labor, A_L in eq. (A.1), is labor saving in small open economies with multiple sectors, as long as the elasticity of substitution between land and labor is smaller than the land share of output, *i.e.* $\sigma < T_a MPT_a / Q_a$. This condition is likely to be satisfied in agriculture, where land and labor tend to be highly complementary.

The model thus predicts that oil palm would reduce the demand for labor in agriculture, and the demand for female labor in particular, as long as the area used for agriculture remains fixed. But as discussed previously, the expansion of oil palm was accompanied by an increase in agricultural land, and substantial deforestation in Indonesia. A simple way to incorporate this into our framework is to model the expansion of land as a function of its marginal product (MPT_a).[4] The effect of an increase in A_M on labor demand in agriculture is then a function of the marginal cost of deforestation. Provided the cost of deforestation is sufficiently low, labor demand in agriculture would remain constant or even increase.

The general equilibrium effect of the oil palm expansion on wages (and incomes) is then a combination of local economy and labor demand effects. Local economy effects are expected to be positive. Landowners benefit from the oil palm expansion because land productivity increases. This increases landowners' incomes, and consumption of the agricultural and the non-agricultural goods. Because the non-agricultural good is not traded, an increase in the demand would raise prices p_n and wages w_n in the non-agricultural sector. To the extent that the non-agricultural sector is characterized by higher returns to education, a growing non-agricultural sector (relative to the agricultural sector) also implies rising returns to education in the economy.

Labor demand effects within agriculture, on the other side, are expected to be negative for women, and weakly positive for men. As the demand for female labor in agriculture falls, women switch from the agricultural sector to the non-agricultural sector. The market clearing condition in the non-agricultural sector is: $w_n = p_n \, MPL_n$. *Ceteris paribus*, an increase in the supply of labor in the non-agricultural sector depresses prices and wages (as long as Q_n is non-tradable). Which of the two effects dominates for female wages in the non-agricultural sector is *ex ante* ambiguous. For men, the general equilibrium effect on wages in both sectors is strictly positive as long as demand for male labor does not decrease in agriculture (*i.e.* as long as agricultural land can expand).

Empirically, the expansion of oil palm was associated with an increase non-agricultural wages for men and women (see Tables 6 and B13), while previous work also found positive effects on men's agricultural wages (Kubitza et al. 2018; Edwards 2019).[5] This suggests that the positive local economy effect dominates the negative labor demand effect for women, and is consistent with our observation that smallholder farmers make up for a substantial share of the palm oil production.

[4] A simple supply function of agricultural land in which there is a fixed cost of deforestation (which is increasing in T_a) is sufficient to characterize an increase in the amount of agricultural land with rising MPT_a.

[5] We explore these effects empirically in Section 6.1.

A.2 Alternative explanations for effect of oil palm on fertility

In the following, we will discuss five potential alternative explanations for why fertility might decline with the expansion of oil palm: Child labor, child mortality, infrastructure, female empowerment, and migration.

Child labor. A negative relationship between fertility and oil palm cultivation might stem from differences in the returns to child labor between oil palm and alternative crops. In many countries, children contribute to household income by working on the family farm or in the labor market, thereby offsetting part of the direct cost of raising children. We are not aware of any detailed empirical analysis of child labor in oil palm cultivation. Anecdotal evidence suggests that children can be involved in picking up loose fruits, which fell off the main bunch during harvest (Koczberski 2007). However, harvesting oil palms necessitates too much physical strength to involve child labor. Rubber and rice cultivation, in contrast, involve more female labor and theoretically also more child labor. We therefore expect that oil palm has reduced the returns to child labor and increased the cost of having children.[6] This could have reduced the demand for children.

Child mortality. Another alternative mechanism could be that fertility decreases as more children survive (Kirk 1996). The idea is that families target a specific number of surviving children, and that this target can be achieved with lower overall fertility rates as child mortality declines. Since oil palm expansion improved incomes and potentially infrastructure, and this probably decreased child mortality, households might have simply adjusted the number of births but not the number of desired children.

Infrastructure. The expansion of oil palm was probably accompanied by substantial investments in infrastructure. The processing of oil palm fruit bunches requires improved road infrastructure and reliable electricity. Moreover, the government of Indonesia targeted infrastructure projects deliberately to oil palm cultivating areas to pursue its economic development agenda.[7] Investments in roads and other infrastructure could reduce the cost of accessing (higher) education and health care services, and encourage investments in child quality, potentially at the expense of child quantity.

Female empowerment. A substantial body of literature suggests that female bargaining power within the household increases as women earn their own income (Duflo 2012). If women have *per se* lower fertility preferences than men, a reduction in fertility could stem from the fact that women's wages in the non-agricultural sector increased. The fertility reduction would then simply reflect an increased bargaining weight of women within the household.

Migration. The oil palm boom increased internal migration flows into oil palm cultivating areas through the transmigration program as well as through spontaneous migration (Euler et al. 2016). In the very short-term, migrant families might have faced increasing opportunity costs of child rearing since the establishment of a new farm and household are labor intensive tasks. On the other hand, men are more likely to be involved in internal migration, increasing the share of women in sending regions (Sukamdi & Mujahid 2015). This could have decreased fertility in sending regions compared to oil palm cultivating areas due to a reduction in the likelihood

[6] Note that the microdata presented in Section 2 do not provide information about child labor, which by 2012 was largely abolished. This does not imply that child labor did not play a more important role in the 1990s.

[7] Furthermore, the oil palm expansion could have directly contributed to the revenue of local governments, which could in turn lead to higher investments in health, education and transportation infrastructure.

of marriage. In the long run, both these factors might be less important, and childbearing patterns might depend more whether there are selection effects, as migrants might have different fertility preferences than the local population (Kulu 2005).

References

Acemoglu, D. (2002). Technical change, inequality, and the labor market. *Journal of Economic Literature* 40 (1), 7–72.

Bustos, P.; Caprettini, B.; & Ponticelli, J. (2016). Agricultural productivity and structural transformation. Evidence from Brazil. *American Economic Review* 106 (6), 1320–1365.

Duflo, E. (2012). Women Empowerment and Economic Development. *Journal of Economic Literature* 50 (4), 1051–1079.

Edwards, R. B. (2019). Export agriculture and rural poverty: Evidence from Indonesian palm oil. Dartmouth College. Hanover, USA. Available online at https://static1.squarespace.com/static/57d5edcf197aea51693538dc/t/5c6cbb1aa4222f75067de956/1550629671736/eard_v9_1901-merged.pdf, checked on 22.02.2019.

Euler, M.; Schwarze, S.; Siregar, H.; & Qaim, M. (2016). Oil palm expansion among smallholder farmers in Sumatra, Indonesia. *Journal of Agricultural Economics* 67 (3), 658–676.

Kirk, D. (1996). Demographic transition theory. *Population Studies* 50 (3), 361–387.

Koczberski, G. (2007). Loose Fruit Mamas. Creating Incentives for Smallholder Women in Oil Palm Production in Papua New Guinea. *World Development* 35 (7), 1172–1185.

Kubitza, C.; Krishna, V. V.; Alamsyah, Z.; & Qaim, M. (2018). The economics behind an ecological crisis. Livelihood effects of oil palm expansion in Sumatra, Indonesia. *Human Ecology* 46 (1), 107–116.

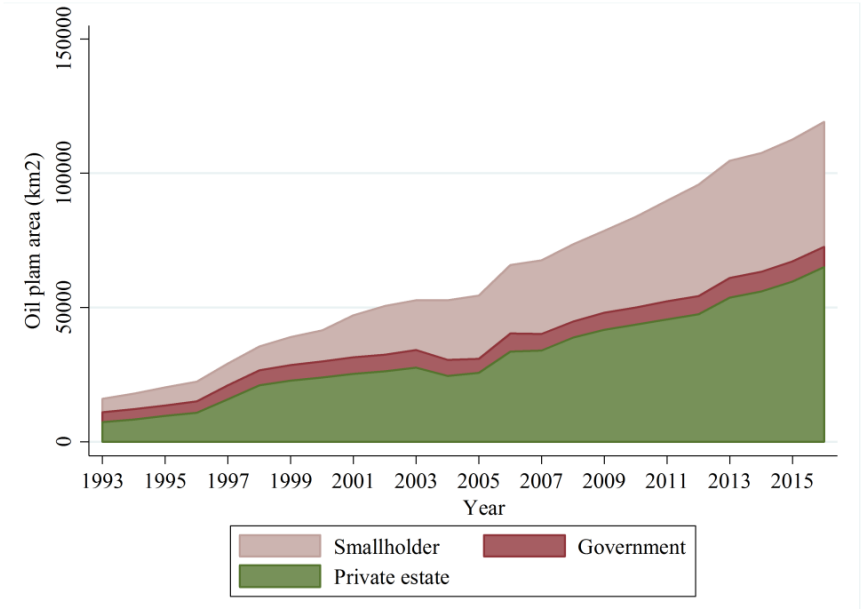
Kulu, H. (2005). Migration and Fertility. Competing Hypotheses Re-examined. *European Journal of Population / Revue européenne de Démographie* 21 (1), 51–87.

Sukamdi; & Mujahid, G. (2015). Internal Migration in Indonesia. (UNFPA Indonesia Monograph Series, 3). Jarkarta, Indonesia: UNFPA Indonesia.

World Bank (2018). Indonesia Database for Policy and Economic Research (INDO-DAPOER). Available online at https://data.worldbank.org/data-catalog/indonesia-database-for-policy-and-economic-research, checked on 25.10.2017.

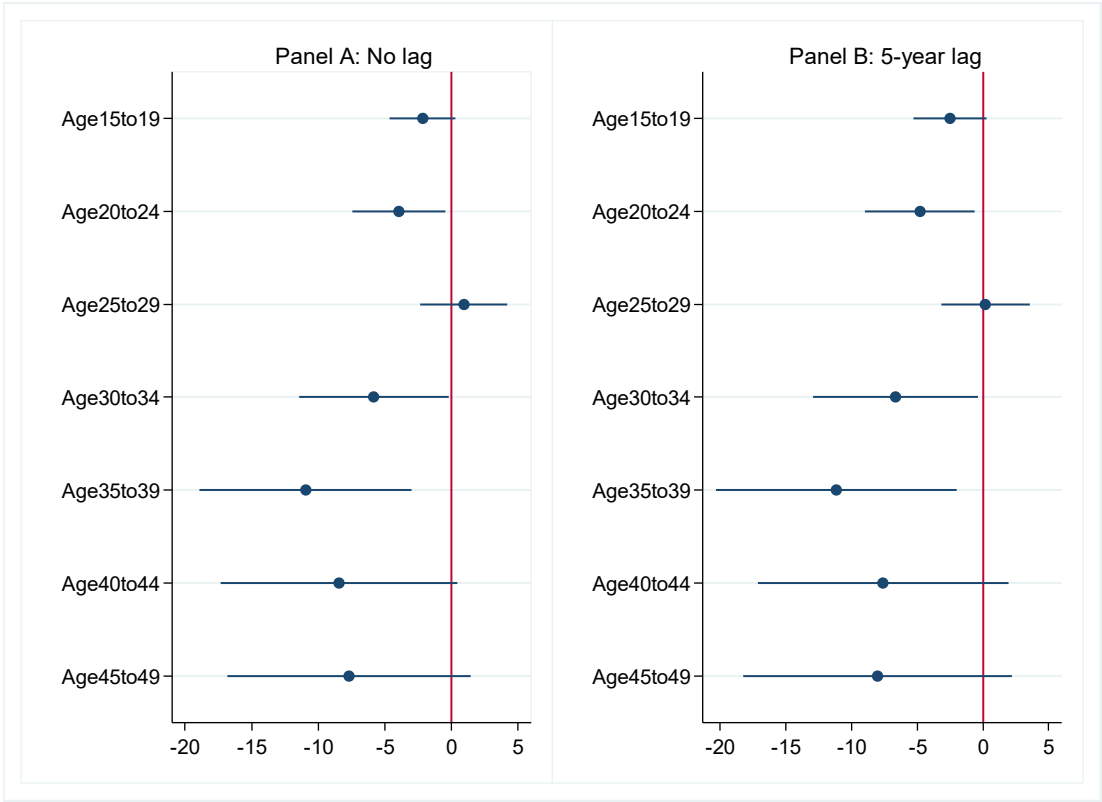
Appendix B: Supplementary Figures and Tables

Figure B1: Expansion of oil palm area in Indonesia by producer type



Source: Tree Crop Statistics.

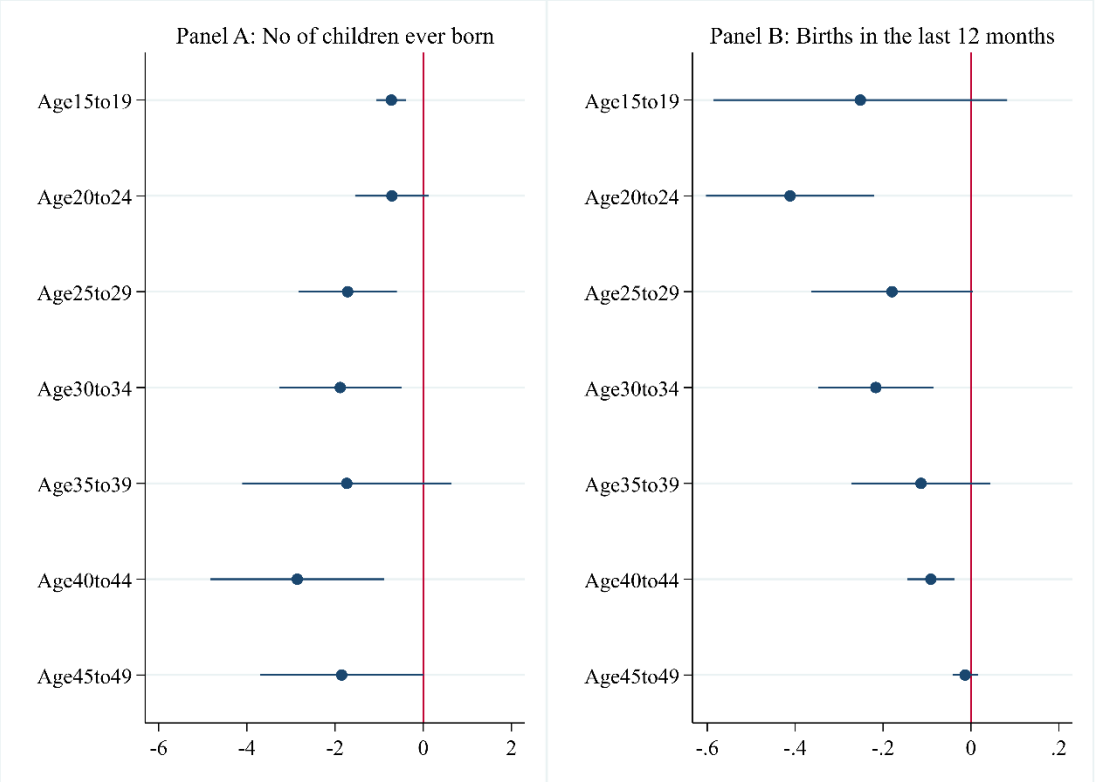
Figure B2: Effect of oil palm on the number of children born by age group



Source: SUSENAS 2001, 2006, 2011, 2016.

Notes: Figure plots marginal effects and 90% CI of IV estimates of the effect of smallholder oil palm area on fertility in 5-year age groups, with standard errors clustered at the regency level. Each regression controls for age fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. Var.: Number of children ever born alive. Sample: Women aged 15-49.

Figure B3: Effect of oil palm expansion on fertility – DHS data



Source: DHS 1991, 1997, 2002-03, 2007, 2012, 2017.

Notes: Figure plots marginal effects and 90% confidence intervals of OLS estimates of the effect of smallholder oil palm area (fraction of province area) on fertility in 5-year age groups, with standard errors clustered at province level. All regressions control for age fixed effects, province fixed effects, and year fixed effects. Dep. var. Panel A: Number of children ever born alive; Panel B: Births in the last 12 months. Sample: Ever-married women aged 15-49.

Table B1: Summary statistics for smallholder household survey in Jambi province

	2012		2015	
	Oil palm farmers [n=238]	Non-adopters [n=441]	Oil palm farmers [n=248]	Non-adopters [n=435]
Household characteristics				
Farm size owned (ha)	5.414 (5.289)	3.337 (3.955)	5.474 (5.224)	3.208 (4.213)
Rubber area (ha)	2.324 (3.485)	3.213 (3.969)	2.170 (3.230)	3.097 (4.217)
Oil palm area (ha)	3.011 (3.656)	0.000	3.212 (3.951)	0.000
Number of household members	4.176 (1.505)	4.218 (1.563)	4.173 (1.500)	4.094 (1.587)
Number of adults in the household (>15y)	2.849 (1.064)	2.980 (1.227)	2.964 (1.125)	2.922 (1.141)
Female-headed household (=1)	0.021 (0.144)	0.068 (0.252)	0.028 (0.166)	0.103 (0.305)
Age of household head (years)	45.51 (12.18)	45.78 (12.28)	47.66 (10.98)	47.49 (11.79)
Educ. of household head (years of school)	7.752 (3.604)	7.302 (3.680)	7.335 (3.526)	7.115 (3.780)
Own business (=1)	0.231 (0.422)	0.186 (0.390)	0.335 (0.473)	0.221 (0.415)
Employed in non-farm (=1)	0.412 (0.493)	0.476 (0.500)	0.556 (0.498)	0.570 (0.496)
Migrant (=1)	0.576 (0.495)	0.374 (0.484)	0.548 (0.499)	0.379 (0.486)
Transmigrant village (=1)	0.437 (0.497)	0.236 (0.425)	0.411 (0.493)	0.248 (0.433)
Total consump. expend. (mill. IDR/year/AE)	24.53 (15.21)	20.09 (31.31)	23.96 (16.75)	17.84 (13.39)
Food consump. expend. (mill. IDR/year/AE)	12.85 (6.57)	10.93 (6.09)	11.61 (6.23)	9.402 (4.761)

Notes: Mean values with standard deviations in parentheses are reported. Monetary values from 2012 are inflation-adjusted. To obtain data on smallholder farms we conducted an extensive survey of local farm household. Data were collected in two waves, 2012 and 2015. Sampling was based on a multi-stage framework. All five regencies in Jambi Province located in the tropical lowland areas were selected purposively. From these regencies, 40 villages in 20 districts were randomly selected. Five additional villages were selected purposively to allow for interdisciplinary collaboration with associated research groups. The sample size was adjusted to village population size to mitigate possible sampling bias. All households that owned any agricultural land in the last 5 years were included. In total 679 randomly selected households were interviewed. Between both rounds, the attrition rate was at 6%.

Table B2: Effect of education on factor productivity of oil palm and rubber

	(1)	(2)
	Profit per ha	Profit per labor hour
Oil palm plot (=1)	439.955	28.995**
	(2036.967)	(11.504)
Education of household head (years of schooling)	126.963	-0.510
	(260.990)	(1.473)
Oil palm plot # Education of household head	-16.070	1.630
	(234.379)	(1.328)
F-Stat	38.976	12.346
Observations	1405	1398

Source: Smallholder household data, Jambi province 2012 and 2015.

Notes: OLS estimates reported. All regressions control for year and household fixed effects, a household wealth index, capital input at plot level and plot size. All monetary variables are in constant 2012 values. Sample: Plots of local smallholder farmers. Unproductive plots were excluded and tree age restricted to main productive age from 5 to 25 years. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B3: Description of data sources

Source	Variable	Data availability	Description
Tree Crop Statistics	Oil palm area	1967-2016 (national level) 1996-2016 (regency level)	We use the data published in the Indonesia Database for Policy and Economic Research (INDO-DAPOER) which is maintained by the World Bank (World Bank 2018), and update the series until 2016 with data from the Tree Crop Statistics Reports (Ministry of Agriculture, 2017). Regency-level oil palm data are only available for smallholders between 1996-2004. Starting 2005, the data contain oil palm area for smallholders, private estates and government estates, such that it is possible to calculate the total oil palm area only from 2005 onwards. Missing data (2006: private and government estates, 2008: smallholder, 2013: all, 2016: private and government estates) are linearly interpolated.
GAEZ/FAO	Attainable yield (kg/ha)	1960-1990 (baseline)	The Global Agro-Ecological Zones (GAEZ) database generates simulations of agro-climatic attainable yields and suitability indices for crops under different conditions in grid cells of 5 arc-minute and 30 arc-second (approximately 10x10km resolution). We use the agro-climatically attainable yield (in kg/ha) for low input level rain-fed oil palm in the baseline period 1961-1990. To convert grid-level data to regency-level data, we aggregate across grids using area weights (*i.e.* total area of the grid overlapping with the regency, divided by the total regency area).
SUSENAS	Fertility (number of children ever born alive), work in the past 7 days (hours, sector of work), educational attainment, school enrollment, child mortality, consumption expenditures per capita	1993, 1996, 2001, 2005, 2006, 2011, 2013, 2016	The National Socioeconomic Survey (SUSENAS) is a multi-purpose socio-economic household survey, that contains individual-level information about demographics, education, and labor market participation, and is carried out annually by Indonesia's Central Statistical Agency, Badan Pusat Statistik (BPS), albeit with altering content every year for some specific modules. The SUSENAS is representative at the regency-level. The provinces of Papua were not covered 2016 due to armed conflict and are therefore dropped from the sample. The province Aceh was not covered in 2001, but because this is an intermediate round, we leave Aced in the sample. As with most surveys, the fertility module is only administered to women who are or were married in the past. To avoid constructing an endogenous sample, we set fertility to zero for all women who were never married. We also winsorize fertility at the 99th percentile. Sector of work is classified into three main sectors: agriculture, manufacturing, and services. The agricultural labor force consists of individuals who are employed in agriculture (such as on oil palm estates), self-employed in agriculture (*i.e.* farmers), and family workers in agriculture. We also use the main activity of the household head to (albeit imprecisely) deduce if a household owns land or not (building on the assumption that a household head who owns land is self-employed in agriculture). Person and household weights are rescaled to give equal weight to each survey year.
PODES	Villages with oil palm cultivation (1993, 2003), Village characteristics (1996, 2006, 2014)	1993, 1996, 2003, 2006, 2014	The Village Potential Statistics (PODES) collects village and urban neighborhood characteristics for all of Indonesia. It is carried out approximately every three years by the BPS. The rounds 1993 and 2003 contain information on village-level land-use. Based on this information, we calculate the share of villages that cultivate oil palm (out of all villages within a regency). We construct additional variables from the PODES rounds 1996, 2006 and 2014, including: the fraction of villages per regency with at least one kindergarten, primary school, junior high school, hospital, maternity facility, asphalt road, and at least one household with access to the electric grid. Villages are reweighted by the number of households.

Table B3: Description of data sources - cont.

Source	Variable	Data availability	Description
SAKERNAS	Wages, work in the past 7 days (hours, sector of work)	1993-2015	The National Labor Force Survey (SAKERNAS) collects labor market characteristics of working age individuals. The SAKERNAS is collected annually by the BPS and is representative at the regency-level since 2007. Regency-identifiers are available from 2000 onwards, and wage data is elicited consistently since 2001. Household identifiers are available in 2003, 2007, 2011, 2015. We construct two samples: 1) In 1993, we calculate average province-level wages for all men and women (aged 15 to 49) employed in the agricultural sector, and the share of women and men working in the agricultural sector. 2) For the years 2001-2015, we extract demographics (age, gender) and labor market outcomes (labor force participation, sector of work, wages per hour) for all men and women in the age-range 15-49. Person weights are rescaled to give equal weight to each survey year.
Demographic and Health Surveys (DHS)	Fertility, Female bargaining power	1991, 1997, 2002/03, 2007, 2012, 2017	The Demographic and Health Survey (DHS) provides representative data on health and population at the province level (village coordinates are only available in 2002-03), including births over the past 12 months (current fertility), and number of children ever born per woman (lifetime fertility) for all ever-married women. We construct some proxies for female bargaining power: 1) the fertility gap is calculated as the difference between actual children and desired children (variable is top-coded at 6). To construct a meaningful measure, we restrict the sample to women ≥40 and bottom code it to zero. 2) Control over her income is a dummy which equals one if a woman earns her own cash salary and reports to decide how to spend it by herself, and zero otherwise (no own salary, or no control). 3) Autonomy is an index ranging from 0 to 1 indicating if the woman reports to be at least partly involved in decisions regarding her own health, household purchases (large and daily), visits to family and relatives and the food to be cooked. The more dimensions she is involved in decision-making, the higher the index (available from 2001-02 onwards). We exclude provinces in Papua to be consistent with the other samples.
IPUMS International Database	Migration, Fertility, Education, Household characteristics, Land-holdings	1971, 1980, 1990, 1995, 2000, 2005, 2010	From the IPUMS International database, we use the 10% subsample of the Population Census of 2010, the 0.54% subsample of 1971, the 5% subsample of 1980, the 0.51% subsample of 1990, as well as the 0.43% subsamples of the Intercensal Population Survey of 1995. We construct three different datasets: 1) From the Census 1980, we calculate regency-level land-distribution characteristics before the onset of the oil palm expansion (median size of agricultural landholdings, number of farmers with agricultural landholdings of different sizes). 2) From the census and intercensal surveys of 1995 and 2010, we construct a sample of all women aged 15-49 that contains their age, education, fertility (number of children born by year *t*), migration history (permanent migration indicates if a woman was born in a different regency than her regency of residence, recent migration indicates if she moved to the regency in the last 5 years). To be consistent with the other samples, we exclude Java, Papua, and city districts (kotas). Person weights are rescaled to give equal weight to each survey year. 3) From the Census 1971, 1980 and 1990 we construct a sample of women aged 15-49 that contains their age and fertility (number of children born by year *t*), which allows us to conduct placebo regressions (we merge this sample to the oil palm area in 1996, 2005 and 2015). Person weights are rescaled to give equal weight to each survey year. To be consistent with the IV estimates from other samples, we exclude Java, Papua, and city districts.

Table B3: Description of data sources - cont.

Source	Variable	Data availability	Description
Badan Pusat Statistik (BPS)	Poverty line	1993-2016	Province-specific rural and urban poverty lines are published annually in the Statistic Year Book of Indonesia. We use rural poverty lines to discount wages and consumption.
NASA	Average altitude	n.a.	NASA's Shuttle Radar Topographic Mission (SRTM) digital elevation data are used to calculate the average altitude of each regency.
Austin et al. (2017)	Oil palm estates	1995, 2000, 2005, 2010, 2015	Spatial data on the expansion of industrial-scale oil palm estates relying on LandSat satellite imagery are published by Austin et al. (2017). Data are available at 250 x 250m resolution for the islands Sumatra, Papua and Kalimantan. We impute zero industrial-scale oil palm estates for Java (main island), where almost no oil palm production is taking place.

Table B4: Additional summary statistics

	Obs.	Mean	Std. dev.
SUSENAS *(1996, 2001, 2006, 2011, 2016)*			
Households:			
Hh head self-employed in agricultural sector	672780	0.454	0.498
Hh head employed in agr. sector	672780	0.076	0.265
Hh head working in non-agr. sector	672780	0.370	0.483
Household size	672780	4.142	1.821
Women aged 15-49:			
Number of children ever born alive (women w/ primary educ.)	394729	2.418	2.098
Number of children ever born alive (women with sec educ.)	296375	1.353	1.603
Number of children ever born alive (women with tert. educ.)	39738	1.426	1.410
Number of children ever born alive (Hh head self-employed in agr.)	329674	2.080	2.081
Number of children ever born alive (Hh head employed in agr.)	55086	1.992	1.802
Number of children ever born alive (Hh head working in non-agr.)	291460	1.874	1.817
Use of contraception (=1)	725678	0.495	0.500
Child mortality (Mortality/1000 children ever born alive)	489879	29.422	113.340
Children aged 10-14:			
Work (=1)	322197	0.068	0.252
Work on own farm (=1)	322197	0.045	0.206
Work (boys) (=1)	167119	0.081	0.273
Work (girls) (=1)	155078	0.054	0.227
SUSENAS *(1996, 2006, 2016)*			
Household:			
Share of food expenditures in total exp.	409108	0.636	0.139
PODES *(1996, 2006, 2014)*			
Regencies:			
Share of villages in regency with asphalt main road	416	0.681	0.188
Share of villages in regency with kindergarten	416	0.574	0.253
Share of villages in regency with primary school	416	0.957	0.084
Share of villages in regency with junior high school	416	0.498	0.173
Share of villages in regency with access to electric grid	416	0.953	0.102
Share of villages in regency with hospital	416	0.039	0.033
Share of villages in regency with maternity facility	416	0.815	0.168
PODES *(1993, 2003)*			
Regencies:			
Fraction of villages in regency with oil palm cultivation	278	0.047	0.116
SUPAS *(1995)*, **Census** (*2010)*			
Men and women aged 15-49:			
Ever migrated to regency	4554189	0.174	0.379
Migrated in last 5y to regency	4543198	0.057	0.233
Women aged 15-49:			
Number of children ever born alive (migrant women)	373294	1.868	1.666
Number of children ever born alive (non-migrant women)	1891718	1.797	1.818
Census *(1971, 1980, 1990)*			
Women aged 15-49:			
Number of children ever born alive	2157735	2.661	2.775

Table B4: Additional summary statistics – cont.

	Obs.	Mean	Std. dev.
SAKERNAS *(2001,2006, 2011, 2015)*			
Men aged 15-49:			
Wages in agricultural sector (IDR/Hour)	239188	1230.246	1882.810
Wages in non-agricultural sector (IDR/Hour)	428801	1499.057	2201.392
Wages with none/primary education (IDR/Hour)	265602	1111.377	1379.413
Wages with secondary education (IDR/Hour)	342992	1387.314	2044.022
Wages with tertiary education (IDR/Hour)	59395	2795.448	3806.942
DHS *(1991, 1997, 2002/03, 2007, 2012, 2017)*			
Ever-married women aged 15-49:			
Age	202109	32.43	9.218
Number of children ever born alive	202109	2.344	1.970
Number of children born in past 12 months	202109	0.108	0.313
Fertility gap (women aged 40-49)	53345	0.676	1.314
Autonomy index	125651	0.868	0.244
Control over income (=1)	202109	0.201	0.401
Tree Crop Statistics *(2006,2016)*			
Regencies:			
Smallholder oil palm area (fraction of regency area)	278	0.021	0.036
Private/ government estate oil palm area (fraction of regency area)	278	0.032	0.057
Share of total oil palm area (fraction of regency area)	278	0.052	0.086
Austin et al. (2017) *(1995, 2000, 2005, 2010, 2015)*			
Regencies:			
Industrial-scale oil palm area (fraction of regency area)	405	0.060	0.085

Notes: All monetary values are in constant 1996 IDR. For migration, multiple regencies have missing data. No data for industrial-scale oil palm area for Sulawesi, Maluku and Nusa Tenggara. One regency missing in PODES data. Autonomy questions available in DHS from 2002/03 onwards.

Table B5: Effect of oil palm on fertility – first stage results

	(1)	(2)	(3)
	Smallholder OP area (fraction of regency area)		
Attainable yield for oil palm *	0.345***	0.196***	0.237***
national oil palm area	(0.066)	(0.049)	(0.060)
Regency & year FE	Yes	Yes	Yes
Woman's age cohorts	Yes	Yes	Yes
Initial levels * year	No	Yes	Yes
Region-by-year FE	No	No	Yes
Kleibergen F-stat	27.576	16.302	15.793
Observations	730842	730842	730842

Source: SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: Dep. Var.: Smallholder OP area (fraction of regency area). Sample: Women aged 15-49. Standard errors (clustered at regency level) in parentheses. The estimates presented here are the first stages to Table 4, Cols. (3)-(5). Attainable yield (in t/ha) and national oil palm area in 1,000,000 ha. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B6: Effect of oil palm on fertility – Local average treatment effect

	(1) Consumption exp. p. c.	(2) Number of children ever born alive
Smallholder OP area (fraction of regency area)	0.194	-0.036
	(0.372)	(0.408)
Smallholder OP area * Attainable yield (t/ha)	1.479**	0.206
	(0.671)	(0.855)
F-stat	3.139	9.350
Observations	672780	730842

Source: SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: OLS estimates are reported. Dep. var.: Col. 1, Consumption expenditures per capita, Col. 2, Number of children ever born alive. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Sample: Col. 1, all households; Col. 2, women aged 15-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B7: Effect of oil palm on completed fertility – women 40-49

	(1) IV	(2) IV	(3) IV
Average 1996-2016 smallholder OP area (fraction of regency area)	-21.137**	-8.439*	-18.069**
	(9.825)	(4.803)	(7.017)
Region and age-group FE	Yes	Yes	Yes
Province FE	No	Yes	Yes
Initial levels * year	No	No	Yes
F-stat	4.662	3.087	11.143
Kleibergen F-stat	11.577	23.149	14.777
Observations	42942	42942	42942

Source: SUSENAS 2016.

Notes: Col. 3 controls for initial levels of regency-average fertility, electrification, female labor force participation, and male agricultural wages, times year. Dep. var.: Number of children ever born alive (lifetime fertility). Sample: Women aged 40-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B8: Effect of oil palm on fertility – PODES data

	(1) OLS	(2) OLS	(3) IV	(4) IV	(5) IV
Fraction of villages in regency with oil palm cultivation	-0.398***	-0.065	-0.936***	-1.092**	-0.992
	(0.126)	(0.149)	(0.335)	(0.548)	(0.710)
Regency & year FE	Yes	Yes	Yes	Yes	Yes
Age-group FE	Yes	Yes	Yes	Yes	Yes
Initial levels * year	No	Yes	No	Yes	Yes
Region-by-year FE	No	Yes	No	No	Yes
F-stat	9.945	3.639	7.803	5.980	3.571
Kleibergen F-stat			42.003	19.904	15.689
Observations	229194	229194	229194	229194	229194

Source: SUSENAS and PODES 1993, 2003.

Notes: Cols. 2, 4-5 control for initial levels of regency-average fertility, electrification, female labor force participation, and male agricultural wages, times year. Dep. var.: Number of children ever born alive. Sample: Women aged 15-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B9: Effect of oil palm on fertility – alternative measures of oil palm area

	(1)	(2)	(3)	(4)	(5)
	Sumatra, Kalimantan, Java		Original sample		
	IV	IV	IV	IV	IV
Smallholder OP area (fraction of regency area)	-2.544		-2.905		
	(1.884)		(2.778)		
Industrial-scale OP area (fraction of regency area)		-1.743			
		(1.250)			
Private/Gov. estates OP area (fraction of regency area)				-1.427	
				(1.432)	
Total OP area (fraction of regency area)					-0.957
					(0.931)
F-stat	14.994	16.211	4.280	4.438	4.472
Kleibergen F-stat	9.976	8.938	11.270	11.332	16.864
Observations	795803	795803	340449	340449	340449

Source: Cols. 1-2, SUSENAS 1996, 2001, 2006, 2011, 2016; Cols. 3-5, SUSENAS 2006, 2016.

Notes: IV estimates are reported. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial levels of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. Var.: Number of children ever born alive. Sample: Women aged 15-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B10: Effect of oil palm on fertility – alternative samples, trends

	(1)	(2)	(3)	(4)	(5)
	Original sample + Java			Original sample	
Smallholder OP area (fraction of regency area)	-9.443**	-5.318**	-3.162**	-5.559**	-5.641***
	(4.201)	(2.353)	(1.304)	(2.449)	(1.765)
Regency, year & age-group FE	Yes	Yes	Yes	Yes	Yes
Initial levels * year	Yes	Yes	No	No	No
Region-by-year FE	Yes	No	No	Yes	No
Province* year	No	Yes	No	No	No
Att. yield of rice * year	No	No	Yes	No	No
Initial levels * National OP area	No	No	No	Yes	No
Average altitude * year	No	No	No	No	Yes
F-stat	8.801	10.938	3.231	5.817	5.463
Kleibergen F-stat	8.564	9.331	23.869	15.849	37.942
Observations	1078267	1078267	730842	730842	730842

Source: SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: IV estimates are reported. All regressions control for five-year age-group fixed effects, regency fixed effects, and year fixed effects. Col. 1 adds region-by-year fixed effects, and initial levels of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Col. 2 adds province-specific linear time trends. Col. 3 adds attainable yield for rice times year. Col. 4 adds region-by-year fixed effects and initial levels times national oil palm area. Col. 5 adds altitude times year. Dep. var.: Number of children ever born alive. Sample: Women aged 15-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B11: Effect of oil palm on fertility – census data, contemporaneous and placebo regression

	(1)	(5)
	Contemporaneous regression	Placebo regression: oil palm area leading by 25 years
Smallholder OP area (fraction of regency area)	-5.942**	-2.060
	(2.871)	(4.262)
F-stat	5.748	4.222
Kleibergen F-stat	9.092	13.837
Observations	2256771	671360

Source: Col. 1, SUPAS 1995, Population census 2010; Col. 2, Population census 1971, 1980, 1990 (IPUMS subsamples).

Notes: IV estimates are reported. All regressions control for five-year age-group fixed effects, regency fixed effects and region-by-year fixed effects and for initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times the national oil palm expansion. The main regressor in Col. (1) is smallholder oil palm area in 1995 and 2010. The main regressor in Col. (2) is smallholder oil palm area in 1996, 2005 and 2015 which was merged with a 25-year lead to the population census. The instrument in col (2) is national oil palm area in 1996, 2005, 2015 times attainable yield. The national oil palm area increased from 133,298 to 294,560 hectares between 1971 and 1980 and to 1,126,677 in 1990. Dep. var.: Number of children ever born alive. Sample: Women aged 15-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B12: Effect of oil palm on main activity of household head

	(1) Hh head self-employed in agricultural sector	(2) Hh head employed in agricultural sector	(3) Hh head in non-agricultural sector
Smallholder OP area	-1.578**	0.914***	0.082
(fraction of regency area)	(0.769)	(0.345)	(0.502)
F-stat	1.732	3.992	1.619
Kleibergen F-stat	16.539	16.539	16.539
Observations	672780	672780	672780

Sources: SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: IV estimates reported. All regressions control for regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Sample: All households. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B13: Effect of oil palm on men's wages

	(1) Non-agricultural sector	(2) Agricultural sector	(3) ≤Primary education	(4) Secondary education	(5) Tertiary education
Smallholder OP area	6.195**	0.750	2.615	4.954*	5.158
(fraction of regency area)	(2.959)	(2.502)	(3.176)	(2.610)	(3.613)
F-stat	3.143	3.105	3.202	1.621	5.934
Kleibergen F-stat	11.389	8.839	8.694	11.971	12.080
Observations	428539	236003	263581	341610	59351

Source: SAKERNAS 2001-2015.

Notes: IV estimates reported. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. var.: Log hourly wages (in constant 1996 IDR). Sample: Working men aged 15-49: Col 1, in non-agricultural sector; Col. 2, in agricultural sector; Col. 3, with none or primary degree; Col. 4, with secondary degree; Col. 5, with tertiary degree. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B14: Effect of oil palm on fertility – subsample analysis

	(1) ≤Primary education	(2) Secondary education	(3) Tertiary education	(4) Hh head self-employed in agricultural sector	(5) Hh head employed in agricultural sector	(6) Hh head in non-agricultural sector
Smallholder OP area (fraction of regency area)	-9.606**	0.444	1.508	-8.490***	-0.700	-4.143*
	(4.280)	(1.174)	(2.980)	(3.107)	(2.270)	(2.303)
F-stat	6.560	1.289	1.556	6.716	6.213	5.722
Kleibergen F-stat	14.784	15.898	13.268	19.539	12.104	12.473
Observations	394729	296375	39738	329674	55086	291460

Source: SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: IV estimates are reported. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. var.: Number of children ever born alive. Sample: Women aged 15-49: Col.1, with none or primary degree; Col. 2, with secondary degree; Col. 3, with tertiary degree; Col. 4, head of household self-employed in agricultural sector; Col. 5, head of household employed in agricultural sector; Col. 6, head of household working in non-agricultural sector. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B15: Effect of oil palm expansion on women's wages - OLS

	(1) ≤Primary education	(2) Secondary education	(3) Tertiary education
Smallholder OP area (fraction of regency area)	-0.533	-0.095	1.355*
	(0.416)	(0.439)	(0.717)
F-stat	5.218	7.874	6.587
Observations	103407	120581	63236

Source: SAKERNAS 2001-2015.

Notes: OLS estimates reported. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. var.: Log hourly wages (in constant 1996 IDR). Sample: Working women aged 15-49: Cols. 1, with none or primary degree; Col. 2, with secondary degree; Col. 3, with tertiary degree. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B16: Effect of oil palm expansion on women's wages – subsample analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	All households			Household head self-employed in agricultural sector			Household head employed in agricultural sector			Household head in non-agricultural sector		
	≤Primary education	Secondary education	Tertiary education	≤Primary education	Secondary education	Tertiary education	≤Primary education	Secondary education	Tertiary education	≤Primary education	Secondary education	Tertiary education
Smallholder OP area (fraction of regency area)	-1.057	-0.028	2.286	-2.095	-0.404	6.373*	1.059	-1.800	-0.121	-0.949	1.252	2.112
	(0.949)	(0.803)	(1.566)	(1.387)	(1.425)	(3.332)	(1.601)	(1.692)	(4.587)	(1.011)	(0.954)	(1.483)
F-stat	1.018	4.436	5.039	2.766	2.641	4.223	1.305	1.428	1.560	2.297	7.054	3.790
Observations	30415	36226	19478	9551	7639	2829	6231	3211	372	11966	21174	13655

Source: SAKERNAS 2003, 2007, 2011, 2015.

Notes: OLS estimates reported. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. var.: Log hourly wages (in constant 1996 IDR). Sample: Working women aged 15-49: Col. 1,4,7,10, with none or primary degree; Col. 2,5,8,11, with secondary degree; Col. 3,6,9,12, with tertiary degree. Cols. 4-12, additionally split the sample by the main activity of household head. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B17: Effect of oil palm expansion on child labor, mortality

	(1) Child labor	(2) On-farm child labor	(3) Male child labor	(4) Female child labor	(5) Child mortality
Smallholder OP area (fraction of regency area)	-1.074**	-0.547	-1.338**	-0.785*	-0.171
	(0.489)	(0.373)	(0.631)	(0.401)	(0.211)
F-stat	1.822	2.696	2.809	1.305	0.653
Kleibergen F-stat	16.188	16.188	16.081	16.275	11.064
Observations	322197	322197	167119	155078	489879

Source: SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: IV estimates are reported. All regressions control for age fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. Var.: Cols. 1, 3-4, work (=1), Col. 2, work in family agriculture, Col. 5, fraction of children born to woman *i* who died. Sample: Cols. 1-2, children 10-14; Col. 3, boys 10-14; Col. 4, girls 10-14; Col.5, women aged 15-49 with 1 or more children born alive. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B18: Effect of oil palm on infrastructure, contraception

	(1) Kindergarten	(2) Primary school	(3) Junior high school	(4) Asphalt road	(5) Electricity	(6) Hospital	(7) Maternity facility	(8) Use of contraception
Smallholder OP area (fraction of regency area)	2.553**	0.928*	0.063	-1.113	-1.436*	0.294*	-0.273	0.723
	(1.161)	(0.554)	(1.038)	(0.931)	(0.852)	(0.175)	(1.261)	(0.534)
F-stat	1.697	2.352	8.620	2.011	19.989	1.122	2.741	1.140
Kleibergen F-stat	27.360	27.360	27.360	27.360	27.360	27.360	27.360	15.789
Observations	416	416	416	416	416	416	416	725678

Sources: Cols. 1-7, PODES 1996, 2006, 2014; Col. 8, SUSENAS 1996, 2001, 2006, 2011, 2016.

Notes: IV estimates are reported. All regressions control for regency and year fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. var.: Cols. 1-7, fraction of villages with respective infrastructure (0-1); Col. 8, use of contraception (=1). Sample: Cols. 1-7, regencies; Col. 8, women aged 15-49. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B19: Effect of oil palm on female empowerment

	(1) Fertility gap	(2) Autonomy	(3) Control over income	(4) Share of food expenditures in total expenditures
Smallholder OP area (fraction of regency/province area)	1.135*	-0.107	-0.004	-0.294
	(0.621)	(0.104)	(0.089)	(0.239)
F-stat	3.337	1.064	0.002	615.031
Kleibergen F-stat				18.122
Observations	53345	125651	202109	409108

Sources: Cols. 1-3, DHS 1991, 1994, 1997, 2002-03, 2007, 2012, 2017; Col. 4, SUSENAS 1996, 2006, 2016.
Notes: OLS estimates reported in Cols. 1-3, and IV estimates reported in Col. 4. Cols. 1-3 control for province and year fixed effects. Col. 4 controls for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Variable definitions are available in Table B3. Sample: Col. 1, ever married women aged 40-49; Cols. 2-3, ever married women aged 15-49; Col. 4, households. Standard errors (clustered at province level in Cols. 1-3 and at regency level in Col. 4) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B20: Effect of oil palm on migration, fertility by migration background

	(1) Ever migrated to regency	(2) Migrated in last 5-years to regency	(3) Fertility (non-migrant women)	(4) Fertility (migrant women)
Smallholder OP area (fraction of regency area)	-2.587**	-0.272	-6.129**	-2.591
	(0.997)	(0.272)	(2.896)	(3.026)
F-stat	6.235	3.091	6.762	1.346
Kleibergen F-stat	9.391	9.376	8.502	8.726
Observations	4537533	4526758	1890143	366628

Sources: SUPAS 1995, population census 2010.
Notes: IV estimates are reported. All regressions control for five-year age-group fixed effects, regency fixed effects, region-by-year fixed effects, and initial values of regency-average fertility, electrification, female labor force participation and male agricultural wages times year. Dep. Var.: Cols. 1-2, migration status; Cols. 3-4, number of children ever born alive. Sample: Cols. 1-2, women and men aged 15-49; Col. 3, women aged 15-49 not migrated; Col. 4, women aged 15-49 migrated. Standard errors (clustered at regency level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.