Export agriculture and regional development: evidence from Indonesia

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Abstract

I measure the impacts of the world's largest modern agricultural expansion—that of Indonesian palm oil since 2000—on regional poverty reduction and consumption growth. Identification exploits geographic differences in suitability for cultivation and rapid growth in global demand. The median areal expansion of five percent of district area led to 2.7 percentage points faster poverty reduction and 4 percent faster consumption growth. The results can be explained by higher agricultural productivity and farm gate incomes, and indirect effects through investments, fiscal linkages, and publicly-provided goods. Each percentage point of additional agriculture-driven poverty reduction also corresponds to around three percent of district area in forest loss since 2000.

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1 Introduction

While growth in trade has been shown to increase incomes and reduce poverty in poor countries in a wide variety of contexts, agricultural export growth is more controversial (Corden and Neary, 1984; Harrison, 2006; Goldberg and Pavcnik, 2007, 2014). Several studies argue that globalization of agriculture discourages structural transformation, leaving areas induced to specialize in agriculture worse off (Mokyr, 1976; Field, 1978; Wright, 1979; Krugman, 1987; Matsuyama, 1992). Others highlight a lack of price pass-through to the farm gate, because of market power in distribution networks and surplus labor on the farm (Bardhan, 1989; de Janvry, Fafchamps, and Sadoulet 1991; Key, Sadoulet, and de Janvry 2000; Fafchamps, 2004; Fafchamps et al 2003). The view that export agriculture—particularly when involving large, capital-intensive farms—is unhelpful for the poor is widely held (Engerman and Solokoff, 2002; World Bank 2008; Byerlee, de Janvry, and Sadoulet, 2009; Easterly, 2007). Yet there is limited evidence on how modern agricultural export growth affects poverty and the distribution of income within countries. Even less is known about the mechanisms through which global agricultural value chains shape welfare in communities they source from.

This study examines the impact of Indonesia's palm oil expansion on poverty and household consumption in rural communities that produce palm oil. Palm oil is the world's leading vegetable oil, found in around half of the products in supermarkets and almost exclusively grown in developing countries. Indonesia's four-fold increase in palm oil production since 2000 is the world's largest modern agricultural expansion and not without controversy. The view that palm oil is not only harmful for the environment, but also the economy and society is common.[1] Coalitions of activists are mobilized around the world arguing in popular fora that palm oil production is environmentally and socially damaging

[1]For example, Koh and Wilcove (2007), Carlson et al. (2013), Busch et al. (2015), Cattau et al (2015), and Gaveau et al (2016) consider the environment. Cooke (2002), McCarthy (2010), McCarthy et al. (2011), and Cramb (2013) describe social issues.

and should be limited through government policy or consumer boycotts. In response, the World Bank placed a moratorium on palm oil related investments in 2009 and the European Parliament voted to ban palm oil imports for biofuels in 2017.

Examining the impact of agricultural growth on poverty is complicated because agricultural output depends on a production process that will depend on correlates of poverty, and because farm gate prices are apt to be correlated with local demand. Indonesia's recent expansion is useful here, as 85% of Indonesia's palm oil is exported. The relevant demand is outside growing communities. To address endogeneity in production, I take advantage of recent growth in demand coupled with the fact that regions differ in their productive potential. Specifically, district areal expansion, in a difference in difference framework, is instrumented with its average agro-climatically attainable palm oil yield interacted with the demand shock. Hence, I examine changes in poverty over time across regions that vary in cultivation intensity due to their potential rather than actual production.

The main finding is that increased palm cultivation delivered geographically-disbursed poverty reduction and broad consumption gains for producing regions. A 10 percentage point increase in the share of district area under cultivation corresponds to an additional 5.36 percentage point poverty reduction and eight percent faster consumption growth. The median areal expansion was five percent of district area. Relative gains were strongest for the bottom 20–60% and I find no evidence of urban households becoming worse off. The magnitude of the effects are economically significant. With national poverty declining from 18.2% to 11.2% from 2002–2015, much of Indonesia's regional development performance can be explained by increased palm cultivation.

I trace the declines in poverty to direct and indirect mechanisms. Since most of the increase in production has come through area expansion (cf. yield increases), a first-order question is whether the impact is simply due to expanding the agricultural frontier. I find that the poverty impacts of increasing the share of farmland under cultivation for oil palm are similar to those using total area as the denominator. My main findings are thus not driven by expansion onto marginal lands, but rather rising returns to labor and land in producing regions (i.e, changes in production). Higher labor productivity in agriculture and manufacturing and higher agricultural wages confirm this interpretation.

Three indirect channels appear to “crowd-in” the direct labor income gains. First, rising household health, education, and durable good expenditures correspond to more assets and floorspace. I interpret these changes as evidence of household-level capital accumulation—a classic theoretical channel linking agricultural productivity to economic development (Lewis, 1954; Rostow, 1956; Johnson and Mellor, 1961), only recently finding empirical support (Bustos et al, 2018; Marden, 2018). Fiscal linkages are the second indirect channel: local government revenue and expenditure grows considerably faster in expanding regions. Since demand for public services is likely lower with rising consumption and falling poverty, fiscal windfalls may be directed to more productive public investments and amplify regional inequalities (Caselli and Michaels, 2013). I find that districts that expanded their oil palm acreage have improved public good provision, including electrification, modern cooking fuel, roads, and marketplaces. At least some these changes are likely “mechanical” and due to the infrastructure needed to process, transport, and export palm oil. Such complementary infrastructure could spill over to other sectors and allow economic returns to ratchet up over time (Allen and Arkolakis 2014; Donaldson, 2015; Martincus et al, 2017; Aggarwal, 2018; Donaldson, 2018), as Dell and Olken (2018) find for Dutch sugar processing on Java.

This study relates to three major streams of research in economics. In addition to contributing new macro evidence to the growing literature on the distributional impacts of trade (Autor, Dorn, and Hanson, 2013; Kis-Katos and Sparrow, 2015; Dix-Carneiro and Kovak, 2016; Costa et al, 2017), my study also builds on a classic tradition of studying the role of agriculture in economic development (Clark,1940; Rosenstein-Rodan, 1943; Nurske, 1953; Ranis and Fei, 1961; Schultz, 1964; Baumol, 1967; Murphy et al 1989; Kongsamut et al 2001;

Gollin et al 2002; Ngai and Pissarides, 2007; Christiaensen et al., 2011; Vollrath, 2011). This burgeoning literature—far too expansive to summarize here—has been relatively quiet on two topics of growing importance.[2] First, in focusing predominantly on the Green Revolution and experiences of rich countries, relatively little is known about modern agricultural growth as driven by the globalized agro-industrial value-chains that characterize our food system today. Second, limited attention has been devoted to cash crops or plantation agriculture, despite their ubiquity today.[3] Agricultural productivity improvements are generally thought to be pro-poor (Kraay, 2006; Ravallion and Chen, 2007), but cash and plantation crops have starkly different implications to food crops—elucidated clearly in Hayami (2010)—and large-scale commercial farming remains highly contested (Engerman and Sokoloff, 2002; Easterly, 2007). The most closely related study to mine is Bustos et al. (2016), which uses cross-region comparisons to show that Brazil's soy expansion led to non-agricultural productivity growth and structural change. I complement this work by measuring impacts on poverty and consumption in local communities where these controversial oilseeds are grown.

My study also relates to a large literature on poverty-environment trade-offs (Grossman and Krueger, 1995; Dasgupta, Laplante, Wang and Wheeler, 2002; Foster and Rosenzweig, 2003; Baland et al 2007; Barbier, 2007; Alix-Garcia et al, 2013; Greenstone and Jack, 2015; Stern et al 2017). I calculate that each percentage point of agriculture-driven poverty reduction has corresponded to between 1.5 and 3 percent of district area lost in tree cover since 2000, and around ten percent more fire. Rural communities and regional governments' revealed preference appears to be the income gains from converting forest to agriculture. Compensation to do otherwise, for example though payments for ecosystem service and other market-based mechanisms, would likely need to be significant and account for these strong economic incentives.

[2] Gollin (2010) and Dercon and Gollin (2014) provide recent surveys.

[3] Exceptions include Pryor (1982), Barbier (1989), Maxwell and Fernando (1989), and Tiffen and Mortimore (1990).

The next section describes Indonesia's agricultural expansion and Section 3 develops the empirical strategy. Section 4 discusses the main findings on poverty and household consumption. Section 5 explores three potential explanations for the main findings, and Section 6 quantifies environmental-economic trade-offs. Section 7 concludes.

2 Background

2.1 The oil palm

The largest agricultural transformation since the Green Revolution has been unfolding over the past two decades. The two most prominent modern agricultural expansions—soy and palm oil, dubbed "the tropical oil crops revolution" by Byerlee, Falcon, and Naylor (2016)—offer a stark contrast to the Green Revolution, being in emerging rather than low income economies, for high-value export crops rather than cereals, driven by areal expansion (extensification) rather than intensification, and led by globalized agro-industrial firms rather than small-scale food producers. From 1990 to 2010, global soybean production grew by 220% and palm oil over 300%, almost exclusively in the developing world. The area planted with oil crops expanded by over 150 million hectares since the 1970s—three times that of *all* cereals.

Palm oil is derived from the reddish pulp of the fruit of the oil palm, a labor-intensive tree crop originating from Africa (*elaeis guineensis*) and the Americas (*elaeis oleifera*) which requires little skill or capital to grow and harvest. It is grown almost exclusively in developing countries today (Corley and Tinker, 2015). The largest costs are land acquisition, transport, and capital-intensive mills, which must receive fruit within 24 hours to be marketable to global markets. Harvesting involves pulling fresh fruit bunches from trees with a long sickle and oil palms bear a relatively consistent amount of fruit around every ten days, with limited seasonality—often a more frequent and predictable income stream than alternative crops.

Yielding more oil per hectare than any other crop (i.e., 4–10 times that of other oilseeds), oil palm cultivation is one of the most economically attractive uses for land in the tropics. Sustained growth in developing countries has led global palm demand to increase from less than 5 million metric tonnes per year in 1970 to over 70 million in 2015, and is expected to further double over the next decade (USDA, 2016).

2.2 Indonesia's expansion

With a comparative advantage in unskilled labor-intensive goods, abundant suitable land, and proximity to India and China, Indonesia was well-placed to capitalize on rising global demand. The devalued rupiah from the Asian financial crisis and the subsequent regime shift devolving power, resources, and responsibilities to regional governments provided the ideal macroeconomic and institutional conditions for the agricultural expansion (Rada et al., 2010). From 1997–2017, Indonesian palm oil production increased from five to over forty million metric tons (USDA, 2018). Over 85% is exported and palm has been Indonesia's largest agricultural export for the last two decades, accounting for more than 55 per cent of the 65 million metric tons produced globally in 2017 (BPS, 2017).

Indonesia's dramatic increase in palm oil production has come almost exclusively through land area expansion, which I plot in Figure 1.[4] Cultivated area increased from 2.9 million hectares in 1997 to over 12.5 million today, comprising (a) farmers shifting crops on existing farmland, and (b) new farmland from scrub, degraded land, or forest (i.e., expanding the agricultural frontier). Since 2000, private sector plantation area doubled and state-owned plantation area remained static, while the area managed by small, family farmers tripled (growing three times as fast as industrial estates). Similar to the increase in Chinese cash crop production studied in Qian (2008) and Marden (2018), the regime shift toward decentralized governance liberalized land use by allowing regional leaders to issue

[4] Gaskell (2015) estimates that 92% of the increase in production is due to land expansion and the remaining 8% due to yield improvements.

permits for new industrial estates and smallholders to easily expand their farms, with little more than a letter or nod from the village head (Naylor et al 2018). Smallholder farms are usually around two hectares each—sometimes managed in partnership with large estates but more commonly independent farmers—and account for over 40% of the area planted today.[5]

The process from planting to exporting is characterized by long lead times. Firms need time to establish the necessary infrastructure, hire workers, prepare land, plant trees, then harvest, process, and export their produce. Figure 2 provides a stylized overview of the sector. Smallholders also need time to switch livelihood, prepare land, plant trees, then wait for the first harvest around two and a half years later. It takes five to seven years for trees to reach a productive state, and the price paid for a fresh fruit bunch increases with tree maturity.[6] Replanting occurs after around 25 years, when yields begin to decline and the fruit becomes difficult to reach. Adoption is thus mostly determined by future demand (i.e., over the medium to long term) and alternative rural livelihood opportunities, rather than any short-term changes in socioeconomic conditions or commodity prices.

Not all land is equally suitable for oil palm cultivation. Humid low-lying tropical areas with ample rainfall provide the ideal growing conditions. Reasonably navigable terrain allows for easier planting, harvesting, and transporting. The combination of rising external demand, decentralized governance, and geographic differences in growing conditions have led to large differences in cultivation intensity across regions, shown in Figure 3. The median expansion from 2000–15 was around five percent of district area, or 42,000 hectares.[7] Districts with above-median suitability (described further below) increased the share of district under

[5]In the Suharto era, industrial "nucleus" estates allocated a portion of new developments to company-supported smallholders, known as "plasma" or "scheme" smallholders (Pramudya et al., 2016). A large share plasma farmers were relocated from Java as part of the national transmigration program. Bazzi et al (2017) and Bazzi et al (2018) study the transmigration program and its modern-day impacts.

[6]Prices are set weekly and published in local newspapers, reflecting limited pass-through of the world palm oil price to local markets (Boyabatli et al, 2017). I include district fixed effects in all estimates to capture any systematic differences across markets.

[7]This figure is for expansion, i.e., districts that increased their area under cultivation. Including also those which did not increase their area under cultivation, the median change in area planted is 1 percent of district area or 6,500 ha. 60 of the 179 rural districts (2000 district boundaries, excluding Java) did not expand their area under cultivation from 2000–2015.

cultivation by 8.4 percentage points (92,000 hectares) more than those below the median, and virtually all districts on Sumatra and Kalimantan—the main producing islands—cultivated some oil palm by 2015.

3 Empirical strategy

Regional agricultural expansion is measured as the area planted with oil palm in each district in 2000 and 2015. Oil palm acreage is digitized from the Tree Crop Statistics of Indonesia for Oil Palm yearbooks, produced annually by the Directorate General of Estate Crops at the Department of Agriculture. District palm acreage is divided by total district area to scale cultivation intensity by district size.

I compare development trajectories in districts with large increases in oil palm cultivation against those with smaller increases or none at all with the specification:

$$y_{d,t} = \delta_d + \delta_t + \beta P_{d,t} + \gamma X_{d,2000} * post + \varepsilon_d \tag{1}$$

where $P_{d,t}$ is the share of district area being used for oil palm farming in 2000 and 2015. The temporal bandwidth of 15 years reflects lags from planting, to harvesting, to exporting. It ensures I compare districts at two distinctly different equilibria, in terms of land use and the mix and level of agricultural production.

$y_{d,t}$ is an outcome of interest in district d at the closest feasible periods to 2000 and the present. My primary outcomes are the district poverty rate and average monthly per capita household expenditures. Both are calculated from the National Socioeconomic Survey (SUSENAS), the annual nationwide survey conducted *Badan Pusat Statistik* (BPS), Indonesia's central statistics agency. Data sources and variable construction for all variables are detailed in the data appendix (Appendix One).

District fixed effects (FEs) δ_d absorb district-specific heterogeneities affecting the local extent of adoption, including geography and climate; historical, cultural, and political institutions; and government policies. District governments and their elected leaders are some of the most important policy makers outside Jakarta, and many laws, policies, and regulations are made and services delivered by districts (Kis-Katos and Sparrow, 2011; Hartwig et al, 2018). Time FEs (δ_t) capture secular trends. $X_{d,2000}$ includes initial rural population shares, literacy rates, agricultural and manufacturing employment shares, and poverty rates, all interacted with a post period indicator to allow differential trends based on initial observable heterogeneities. Results thus depend on comparisons between districts with the same initial initial level of development, urbanization, and distribution of employment across sectors. Robust standard errors are clustered at the district level.

I modify the two-period district panel in three ways to improve counterfactual comparisons. First, I apply 2000 district definitions to work with a balanced panel of constant-area geographic units, given my focus on land use.[8] Second, I remove cities, where little palm is grown but palm oil companies are often headquartered (growth could thus affect economic outcomes in cities). Third, Indonesia's richest, most populous island of Java grows little palm, has many more districts than other islands, and is the island that outer islands are converging toward for reasons other than agricultural growth (Hill, 2014; Bryan and Morten, 2018). I remove districts on Java to compare only rural districts across outer islands and minimize any potential convergence confound.[9]

I stress that Equation 1 identifies the impacts of agricultural expansion in *regions* that expanded cultivation relative to those that expanded less or not at all. It does not identify *aggregate* effects for Indonesia as a whole, but rather the general equilibrium effects at the regional level assuming no spillovers across regions.

[8]Indonesia's "big bang" decentralization saw the number of districts proliferate from 282 in 1998 to 514 in 2015. Bazzi and Gudgeon (2018), Burgess et al (2012), and Fitriani et al (2005) describe the balkanization, highlighting how districts splits followed subdistrict boundaries and did not affect neighboring borders.

[9]Appendix Tables 1–4 and 8–11 show that my main results are qualitatively similar with Java, with cities, with island-by-year fixed effects, and when iteratively leaving out each major island group.

3.1 Identification

My identification strategy combines the difference-in-difference specification in equation 1 with an instrumental variable (IV) exploiting geographic differences in suitability and the external demand shock. Suitability is measured as average district agro-climatically attainable palm oil yield, calculated from the Food and Agriculture Organization's (FAO) Global Agro-Ecological Zones (GAEZ) dataset.[10] To construct my instrument, I map gridded data on crop-specific potential yields to district boundaries, take district means, and interact average district agro-climatically attainable palm yields with a post-period indicator to induce temporal variation.

The first stage intuition is that higher potential yields increase the likelihood of developing palm processing infrastructure and planting trees.[11] This relationship should strengthen with the increase in demand and regime shift liberalizing what can be planted where. Panel A of Figure 4 shows this graphically, with a binned scatter plot of potential palm yields against the share of district area under cultivation. The weak but positive relationship between potential yields and cultivation area in 2000 came to life by 2015, particularly in the most suitable districts. In this regard, my approach is similar to Nunn and Qian (2011), Bustos et al (2016), and Gollin et al (2018), relying on an external shock to "turn on" GAEZ-based identifying variation.

[10] GAEZ uses agronomic models and high resolution geographic and climatic data to predict attainable yields for 1.7 million grid cells across the Earth. The model does not involve estimating any sort of statistical relationship between observed inputs, outputs, and agro-climatic conditions, and estimates are available for different crops on every piece of land, regardless of whether the land is cultivated. See Costinot et al. (2016) and Fischer et al. (2002) for further details. Other measures of palm suitability are available (e.g., Pirker et al 2016), but GAEZ is preferred here because (a) it is free from endogenous local variables contaminating calculations and (b) consistent estimates are available for substitute crops.

[11] Qualitative evidence gathered from firms suggests that suitability is the first-order concern when developing plantation infrastructure. Farmers are also highly attuned to the relative profitability of adopting, usually from observing neighbors.

The crucial identification assumption is that potential palm yields do not affect poverty through any channel other than palm cultivation. Clearly, the primary channel for potential palm yields to affect economic outcomes must be through growing palms. However, one might still be concerned that highly suitable districts differ in other ways potentially correlated with adoption and development trajectories. Table 1 presents descriptive statistics for sample districts above and below the median palm yield. Highly suitable districts are observably different in terms of poverty, literacy, and rural population already included in $X_{d,2000}$, as well as in other ways.

I provide three types of evidence supporting the exclusion restriction. First, I show that estimates are not particularly sensitive to the inclusion of additional trends (Table 2 and Appendix Tables 1 and 2). For example, a key input to the palm oil GAEZ productivity model (e.g., rainfall) could affect productivity of similar tropical crops and therefore welfare through unrelated changes in production in other agricultural sectors (Sarsons, 2015; Bazzi and Clemens, 2013). Using a crop-specific instrument mitigates this threat, but I go a step further and show that estimates are similar if I include potential yields for key cash crops with similar growing conditions (cocoa, coffee, and teas).[12] For remaining differences and any geographically-distributed unobservables not well captured in $X_{d,2000}$, I show that estimates are similar if I include a battery of additional trends, including a polynomial in latitude and longitude. I also show that results are similar including island-by-year fixed effects, which capture any time-varying regional confounding and restrict my comparisons to districts on the same island (Appendix Tables 1 and 2).

The second set of checks I provide are falsification tests asking whether pre-period poverty and consumption are statistically related to subsequent oil palm expansion and my instrument (Appendix Tables 5 and 6). The absence of any statistically significant placebo

[12]Note that for potential yields of other crops to pose a threat for identification, they must also "switch on" over the 2000s and be correlated with the increasing salience of potential palm yields over the 2000s. Agro-climatic suitability data for rubber, replaced in many areas by oil palm, is unavailable in the GAEZ dataset.

effects suggests that my main estimates are not picking up unobserved preexisting trends. Finally, I follow Nunn and Wantchekon (2011) and provide additional falsification tests exploiting the reduced form (Appendix Table 7). I show that the reduced form relationship between suitability and poverty only exists in palm growing regions, and that economically and statistically significant effects only emerge for palm suitability in a model saturated with the potential yields of many other crops.

Table 2 presents first stage results. Column 1 is my preferred specification, including only the instrument, district and year FEs, and five baseline initial conditions trends.[13] A potential yield of an additional metric ton per year corresponds to 2.1% more of the district being planted (shown graphically in Panel B of Figure 4). The p-value of 0.0004 is less than a quarter that needed to arouse concern about a potentially weak instrument (Staiger and Stock, 1997). Column 2 adds differential trends related to cocoa, coffee, and teas. The coefficient on palm yield is statistically indistinguishable from that in Column 1, suggesting potential productivity of other agriculture is not a major concern for identification. Column 3 saturates the model with additional trends related to remaining differences in Table 1—ethnolinguistic fractionalization, the share of villages in each district with palm farmers, district production in tons, population density, and the percentage of households with access to electricity. Column 4 adds a polynomial in latitude and longitude to purge remaining geographic confounding. Column 5 adds the change in the district poverty rate over the 1990s to explicitly factor in pre-trends. Across these demanding specifications, the point estimate is stable, standard errors small, and first stage robust. Analagous second-stage and OLS estimates are in Appendix Tables 1–4.

[13] The minimal specification is my preferred specification because I consider it the most transparent and, given the exogeneity of the GAEZ data and the evidence presented throughout this section and the appendix, I do consider additional covariates essential for identification. The minimal specification provides more conservative estimates than several of the more saturated models and the strongest first stage identification, which I consider crucial to maintain as I move to the household and individual level and the excluded F statistics become less informative due the district-level identifying variation.

Exploiting the variation in expansion arising from crop-specific agro-climatic suitability isolates the effects of developing oil palm on land where it makes the most economic sense to develop it. Here, "economic sense" relates to purely natural agro-climatic characteristics, not other sources of profitability like market access, trade costs, or input (e.g., land and labor) costs. The local average treatment effect (LATE) may be different to those relating to these other sources of profitability, adopting in places less suitable, or the average treatment effect (ATE). An alternative approach would be exploiting the differentiated timing of suitability, as Nunn and Qian (2011) do for potato and Bustos et all (2016) for soy. With the benefit of cultivation data, I can go further than the "reduced form" to identify the impact of expanded cultivation using IV. An additional benefit of an IV approach arises because some suitable districts do not cultivate palm. Including them as treated units understates adopter effects. The LATE relating to more exogenously-driven adoption behavior is thus not particularly narrow and is in fact ideal, as the policy-relevant parameter of interest with the most credible identification.[14]

4 Regional poverty reduction and consumption growth

Indonesian districts converting more of their land for oil palm cultivation since 2000 achieved more rapid poverty reduction. Figure 5 shows a simplified version of the main result in the raw data over the 2000s, comparing the average poverty rate of rural districts with the most oil palm expansion against those without and the national district average. Rural districts had similar poverty levels in the early 2000s but districts more intensively increasing production diverged as the decade progressed.

[14]Consistent LATE estimation requires the extent of areal expansion to increase monotonically with suitability. Panel B of Figure 4 shows this. Higher potential yields are unlikely to push districts to cut back their palm production, at least not during the period of this study while palm cultivation is still a productive use of land compared to alternatives.

Table 3 presents the main regression estimates of the impacts of agricultural expansion on poverty (Columns 1–3) and average per capita household consumption (Columns 4–6). Each column reports a different version of Equation 1. Columns 1 and 4 give the OLS relationships with cultivated area. Columns 2 and 5 report my preferred IV estimates. Columns 3 and 6 report the reduced form using average district agro-climatically attainable palm yield interacted with a post-period indicator. All include district and year fixed effects and separate trends for different initial levels of economic development, urbanization, and labor market structures. The OLS point estimate on oil palm land in Column 1 is -0.081, but increases in magnitude to -0.536 when instrumented with post*suitability. This means that a ten percentage point increase in the area under cultivation for oil palm in a rural district, due to that district being more suitable, corresponds to an additional 5.36 percentage point reduction in district poverty. The median areal expansion is around five percent of district area. The reduced form relationship between suitability and poverty (Column 3) shows that districts with an average potential palm yield of an additional metric ton per hectare per year higher reduced poverty by 1.2 percentage points more. These effects are not trivial compared to the overall decline in national poverty from 18.2% to 11.2% from 2002–2015 and echo Suryahadi et al (2009) on the importance of agricultural growth for rural poverty reduction in Indonesia.

Columns 4–6 of Table 3 present estimates on average per capita household expenditure. Additional household-level controls for living in an urban area, household size, and primary sector of income are included to improve precision. Although incomparable, the OLS coefficient of 0.001 again illustrates the biases that OLS might introduce relative to the IV and reduced form specifications. The IV coefficient is 0.008, meaning the median areal expansion of 5 percent of district area corresponds to a 4 percent faster increase in average per capita household expenditure. The reduced form estimate finds that a potential yield of an additional metric ton corresponds to 1.8% faster consumption growth.

4.1 Effect heterogeneity across households

A natural question to ask next is for which households is expenditure rising? In other words, which groups are driving the poverty reduction? To answer these questions, I classify SUSENAS households based on whether they derive most of their income from agriculture and whether they live in rural or urban areas. Since cities are dropped, urban households are those living in urban villages, i.e., small towns (*kelurahan* in Indonesian) in rural districts.

Figure 6 reports IV estimates for total, food, and non-food expenditure for all households and each of the four groups. The first point from the top is the average effect on total per capital household consumption (Column 5 of Table 3), for reference. Average effects are driven predominantly by rural households—in and out of agriculture—and by non-food expenditures (i.e., health, education, and durable goods), which increase by over three percent for a single percentage point increase in palm area. Since most rural poor rely on agriculture for a livelihood (as smallholders or laborers), rising agricultural incomes is the most plausible explanation for the poverty reduction. I find no evidence of any effect on total expenditures for the average urban household, but this masks a shift from food to non-food spending.

Despite positive impacts for the average household, my main poverty findings could be due to people near the poverty line being lifted just above, with little effect on the extreme poor. Figure 7 presents the distribution of per capita household expenditures in 2015 for households in non-producing, mild producing, and major producing districts with over 20% of their area planted. The distribution shifts progressively to the right with cultivation intensity and the consumption "floor" is considerably higher in producing districts. To explore distributional impacts more formally, Figure 8 presents IV estimates of the effects on household expenditure for each decile. Households in each district-year are divided into deciles based on their total per capita expenditures and each is used in the same manner as in Figure 6. This approach is conceptually similar to extracting out percentiles for each district, as in Topalova (2010) and others, assuming rank equivalence and a stable distribution over time. Panel A of Figure 8 finds that the poorest 10% consume 2.5% more in the median expansion district relative to the poorest 10% in a counterfactual district with no expansion. This is not particularly surprising since the landless often work on large industrial estates and assisting smallholders, whose largest production-related expenditure is hired labor (BPS, 2013). The bottom 20–60% experience the largest relative gains, with effects tapering off for the upper-middle class and ratcheting up again for top 10%. In Panel B I present the same estimates with expenditure in Indonesian rupiah (i.e., not logged) to highlight how the relative gains in Panel A translate into absolute dollar terms. The median household, experiencing the median expansion, has roughly an additional $3.5 USD per person per month—roughly four days more consumption above the poverty line.

5 Mechanisms

5.1 Conceptual framework

This section explores three potential explanations for the main findings. First, any poverty benefits from expansion could be purely a direct labor income story for smallholders, workers on industrial estates, or people employed elsewhere in the supply chain. However, in a setting of relatively abundant labor and reliance on land as a factor of production, increasing farmland alone (cf., raising productivity) could increase agricultural output and reduce poverty. Hence I first clarify the sources of the direct income gains by exploring whether expanding the agricultural frontier explains most of the effect (cf., crop-switching and rising returns to land on a per hectare basis) and whether returns to labor are rising in expansion regions.

Indirect effects could see the gains increase over time. I hypothesize and test three channels for agricultural surpluses to "crowd-in" regional development. First, households could be investing in productive assets and human capital. Second, local governments could do the same. Regional autonomy provides apt opportunities for local governments to raise revenue from a growing economy and natural resources, including levies on natural resources. Fiscal linkages and publicly-provided goods could be important in explaining regional disparities. For example, Feler and Senses (2017) document low labor demand in trade-exposed regions of the United States causes local government revenues and services delivery to decline, despite greater need with higher unemployment and poverty. Third, export orientation and immediate processing requirements mean that any local infrastructure development may be partly mechanical—a necessary condition to expand production.

Finally, district poverty rates can fall due to real consumption growth for the poor or through changes in population. Indonesia has high levels of intra-national mobility compared to other developing countries and migration impacts from local agricultural growth are theoretically unclear (Bazzi, 2016). An increase in rural incomes could spur migration from urban areas back to the countryside (Harris and Todaro, 1970), while rural income growth could alleviate financial constraints to mobility (Bryan et al, 2014). My final mechanism analysis thus explores the plausibility of an alternative migration-based explanation for my results, focusing on the quantum and composition of flows.

5.2 Direct effects—frontier expansion and productivity

Table 4 reports regional poverty impacts incorporating information on the area under cultivation for all types of agriculture. Total district farmland is calculated as the sum of village farmland reported in the 2003 and 2008 *Potensi Desa* (PODES), the triennial census of village heads. The temporal bandwidth reflects the shorter period. For comparison, Columns 1 and 2 report the main OLS and IV results from Table 2 estimated for 2003—2008 (cf., 2000—2015). Marginal effects are larger than those in Table 2. 2008 was the peak of the food price crisis, when palm oil prices also peaked. To clarify the poverty elasticity of crop-switching relative to the aggregate effects including frontier expansion, Columns 3 and 4 denominate palm oil acreage with total district farmland. The OLS point estimate is not statistically different from zero. The IV estimate, however, is indiscernible from that using total district area (Column 2). The heavily overlapping confidence intervals suggest that the main results are not driven by new farmland and expansion of the frontier, but rather its particular use (i.e., changes in production within agriculture). Columns 5–8 probe this conjecture further from slightly different angles. Column 5 looks at whether increasing farmland, regardless of its use, corresponds to faster poverty reduction (i.e., farmland as a share of total area is the explanatory variable). The point estimate is one third of that in Column 1, although the confidence intervals still overlap. The final two columns use level explanatory variables to run a "horse race" between an additional hectare of oil palm versus any farmland. Palm wins by a factor of eight.

To explore the importance of within-agriculture changes in production a little further, I estimate impacts on labor productivity and wages in Table 5. Columns 1 and 2 use average district output per worker in agriculture and manufacturing as dependent variables. Columns 3–6 use average wages. A one percentage point increase in area under cultivation for palm oil corresponds to 160 million rupiah (12,000 USD) more output per worker per year in agriculture, 685 million (45,000 USD) more in manufacturing, and four percent faster wage growth across all sectors. Wage growth is almost entirely driven by agriculture. Rural services, by comparison, are often unskilled, unproductive, and informal, and manufacturing labor is typically skilled, mobile, and limited, with wages equalizing across regions. While these numbers might seem large, it bears emphasis that returns disproportionately accrue downstream, and that these estimates are also likely to be upper bounds due to (a) the LATE interpretation and (b) potential measurement error in employment.

5.3 Indirect effects—savings, investments, and public goods

To explore what households are doing with their rising incomes, the first three panels of Figure 9 disaggregate impacts on non-food expenditure by expenditure and household type. All types of non-food expenditure increase, for all groups. Consistent with Foster and Rosenzweig's (1996) analysis of Green Revolution in India, low-skilled, labor-intensive agricultural growth does not appear to be discouraging households from investing in human capital. The remaining panels of Figure 9 examine whether higher durables spending corresponds to household asset accumulation. Households in the median expansion district are twenty percent more likely to own a major asset and have on average three percent more floorspace.[15] The final panel of Figure 9 finds that the average household in the median expansion district five percent more likely to be connected to the electricity grid and serviced by *Perusahaan Listrik Negara* (PLN), the main electricity company.

Panel A of Table 6 reports effects on local government revenue and expenditure. Columns 1 and 2 find that total district government revenue and spending are almost twenty percent higher in the median expansion district. Columns 3 and 4 turn to villages—the key organizing unit in the Indonesian countryside (Olken, 2007; Alatas et al, 2012; Antlov et al 2017; Martinez-Bravo, 2017)—and add village-level controls for urban villages (*kelurahan*), geographic characteristics (e.g., coastline, hilly terrain), and primary sector of income. I find that the median district agricultural expansion has allowed the average village in that district to generate 35% more own source revenue and increase expenditure by 25%.[16]

[15]Home extensions—in addition to motorcycles (counted in assets)—are often the first thing a rural household will buy following an income windfall so a good proxy for rural financial health. I cannot distinguish between productive and non-productive assets across SUSENAS 2002 and 2015.

[16]Estimates disaggregating revenue and expenditure by type and using transfers as placebos are in Appendix Tables 17 and 18. Note also that own source revenue is the smallest revenue stream for villages. Most of it comes in a grant from the central government known as the *Dana Desa* and districts provide additional transfers, often in-kind in the form of health clinics, schools, and other infrastructure.

Against a background of rising household incomes, increased fiscal capacity, and a potential mechanical increase in supply chain-related infrastructure, Panel B of Table 6 examines publicly-provided goods.[17] Figure 9 showed small but precisely estimated impacts on households' access to electricity. Column 5 of Table 6 finds an economically large improvement in village access to clean cooking fuel—that is, using gas or kerosene provided through utilities and markets, instead of self-collected firewood or dung. Columns 6 and 7 consider village road quality: whether roads have been upgraded from dirt to hardened gravel or asphalt, and whether roads are fitted with street lights. The point estimate for palm land in Column 6 is small, but precisely estimated.[18] Column 7 reports that the average village road in the median expansion district is 6.5 percent more likely to be fitted with a street light, consistent with the electrification results and the lower costs of fitting the light versus upgrading and maintaining the road. Finally, Column 6 uses an indicator for whether a village has built a permanent, physical market as a dependent variable. Markets are centers of commercial exchange, helpful for organizing agricultural activities and aggregating harvests. A ten percentage point increase in district area under cultivation for palm leads to the average village in that district being four percent more likely to have built a market since 2000. With only sixteen percent of rural villages having markets in 2014 (up from 12 percent in 2003), the effect size is economically significant.

[17]It bears emphasis that my approach picks up only average effects across all villages in treated districts. Unless districts increase public good provision across their entire jurisdiction, impacts will be concentrated around factories. In companion work, I find this is indeed the case (Edwards, 2018).

[18]Road upgrades mostly use hardened gravel rather than higher-quality asphalt. In fact, villages in expansion districts are less likely to have asphalt roads. That rural villages are not undertaking the "last mile" of road development is unsurprising. Villages in palm oil producing regions are usually remote, with poor quality roads, little capital machinery apart from that around the factory, and intense rainy seasons. Firms focus investments around their estates and factories, not their broader "supply shed" or district. Estimates on all categories of road quality are provided in Appendix Table 19.

5.4 Migration

Table 7 reports migration rates from the 2000 and 2010 Population Censuses to highlight four stylized facts. First, rural districts in the outer islands (i.e., my estimation sample) have similar migration rates to all of Indonesia. Second, lifetime migration rates are around four times that of recent migration (i.e., within the last five years). Third, in 2010 2.5 percent of people reported living in a different province in 2005. Fourth, inter-district migration is almost twice as common as inter-province migration. 4.6 percent of respondents report moving district in the last five years. This quantum is somewhat smaller than the poverty reduction in the median expansion district.

Three types of population changes could contaminate my findings: (a) differential population growth (i.e., altering compositions); (b) inward migration of non-poor people from non-producing districts (cf., wealthy beneficiaries of natural resource sectors residing in cities and non-poor preferring to migrate to cities); and (c) outward migration of poor people. I explore each in turn.

Table 8 presents estimates of the impacts of palm expansion on different population outcomes. I use as the explanatory variable the share of district area under cultivation for oil palm in 2000 and 2010, but all else is the same. Column 1 estimates impacts on total district population. Although regional economic growth could plausibly affect fertility patterns (Grimm et al 2015), I cannot reject the null hypothesis of no effect on population. Estimating the main results weighted by population, so small districts where a given level of migration poses more of a threat are weighted less, are also similar (Appendix Tables 20 and 21).[19] Columns 2 and 3 examine inter-district and inter-province migration rates, finding that expansion districts have slightly less inward migration.

[19] Note that population weighting, of course, assigns less weight to expansion regions, so this is not my preferred estimation approach.

That migration to expansion districts is less common than elsewhere is reassuring, but these results do not tell us whether low-income people are leaving. Figure 10 shows the probability of migrating by level of education, since censuses do not have data on income. Mobility increases with education, and cross-district migration is twice as common as cross-province migration at all education levels. These patterns are similar in high and low suitability districts (Appendix Figure 1), and consistent with qualitative evidence gathered from field visits.

The common narrative around displacement focuses on agroindustrial frontier expansion (Li, 2011; White and White, 2012; Cramb and McCarthy, 2016), but this downplays the prominence of smallholders (Naylor et al, 2018). Plasma scheme smallholders mostly moved in during the transmigration program, which ceased in 2000. Independent smallholders account for most of the recent growth and tend to be local people without government or company support, less affluent and more hesitant to move. Local language differences, especially among the poor, exacerbate these tendencies. A district is a large geographic unit, on average comprising over 200 villages. When villages are forcefully moved or formal relocation agreements reached, communities tend to be relocated nearby or incorporated into plantation activities within the same subdistrict (or village, if large enough). Relocation to other districts is rare and a displaced individual is unlikely to move beyond the district or provincial capital, in no small part due to financial constraints.[20] Although I cannot rule out poor people systematically leaving palm-growing districts and being replaced by non-poor inward migrants, it seems unlikely to fully explain my results.

[20] Province-level estimates— which remove the influence of any cross-district migration within provinces—are qualitatively similar (Appendix Table 22), suggesting intra-province migration is not substantially affecting my findings.

6 Environment-poverty trade-offs

An extensive literature highlights environmental costs often associated with poverty alleviation and the public debate surrounding palm oil focuses almost exclusively on environmental concerns. To calculate the local environmental trade-offs arising from an oil palm-driven change in poverty, household expenditures, or any other outcome, I relate district-level environmental degradation to changes in cultivation area since 2000 with the equation:

$$y_d = \beta(P_{d,2015} - P_{d,2000}) + \gamma X_{d,2000} + \varepsilon_d \tag{2}$$

where y_d is forest loss as a share of total district area (Hansen et al, 2013) or thermal hotspot detections since 2000 (Langner and Siegert, 2009). Fire is the main way farmers clear land. $P_{d,2015} - P_{d,2000}$ is the change in the share of district area under cultivation, instrumented with suitability. Since forest loss data cover the whole period since 2000 and fire data are highly seasonal (mostly due to El Niño), I opt for the cross-sectional long-difference analogue of the main panel specification (equation 1). $X_{d,2000}$ includes the same initial conditions controls.

Environmental impacts are presented in Table 9. Columns 1–3 present OLS, IV, and reduced form estimates for district forest loss from palm oil expansion since 2000. The OLS and IV estimates suggest that a one percentage point increase in district area under cultivation on average corresponds to between an 0.8–1.7 percentage point loss in forest cover. Columns 4–6 use district hotspot detections since 2000 as the dependent variable and Poisson estimation since data are counts. Hotspot detections increased by roughly eight percent for each percentage point increase in the share of a district planted with palm since 2000. These large and precisely estimated effects confirm that agricultural growth, forest loss, and fire have—at least over the last fifteen years—gone hand-in-hand in the Indonesian countryside (cf., Foster and Rosenzweig, 2003).[21]

[21] My main poverty and consumption estimates are net any countervailing public health impacts (Frankenburg et al., 2005; Sheldon and Sankaran, 2017), which could plausibly stymie poverty reduction.

What is the poverty-environment face-off that regions face when considering a development strategy based principally around agricultural growth, at least if it is pursued in the same manner as the last 15 years? My estimates suggest that each percentage point of poverty reduction that has been achieved through extensive palm oil expansion since 2000 has come at the cost of between 1.5 and 3 percent of district area lost in tree cover and around ten percent more fire. To continue Indonesia's agriculture-driven poverty reduction without these significant environmental costs, growth will clearly need to move from extensive to the intensive margin, toward land with considerably lower conservation value, or away from fire as a tool to manage land.[22]

7 Conclusion

This paper measured the impacts of Indonesia's rapid increase in palm oil cultivation from 2000 to 2015 on regional poverty. Although national poverty continued to decline since the fall of Suharto in 1998, rural areas more intensively increasing palm oil production experience faster poverty reduction. The magnitude of the effect is not trivial. National poverty declined from 18.2% to 11.2% from 2002–2015, but the median expansion district reduced poverty around five percentage points faster than an otherwise similar rural district. Consumption impacts are also significant, with four percent faster consumption growth in the median expansion district. Indonesia's recent agricultural growth thus provides an important case study of how geographically-dispersed pro-poor growth can reach remote regions.

My findings line up behind large bodies of theory and evidence emphasizing the benefits of trade and the importance of agriculture for managing and alleviating poverty in developing countries. I find little empirical support for the views that agricultural exports are a different, more harmful type of trade for developing countries, or that export-oriented commercial

[22] In the environmental and agricultural sciences, Fargione et al, (2008), Koh and Ghazoul (2010), and Phalan et al (2016), Soliman et al (2016), and Wottiez et al (2017) discuss such strategies.

agriculture functions as an economic enclave and brings little benefit to local communities (cf., Engerman and Solokoff, 2002; Bebbington et al, 2006; Obidzinski et al., 2014), at least in the context of Indonesian palm oil. Evidence on the channels at work clarify why. Impacts are coming mostly through productivity-driven increases in farm gate incomes and rural capital accumulation, and an increasingly outward, market-oriented agricultural sector is "crowding-in" gains through improved local fiscal capacity and public good provision.

The approach taken in this paper precludes any conclusions regarding whether increased palm oil cultivation causes faster or slower *aggregate* poverty reduction at the *national* level. Future research could structurally estimate aggregate impacts and explore factor reallocation in more detail. Understanding the role of new agricultural manufacturing factories in reshaping rural economic geography also seems important, and my findings highlight the need to better understand how to align environmental and economic outcomes. Given the strong political momentum to reduce Indonesia's persistent forest fires, trialling interventions to curtail the use of fire as a tool to manage land could be promising.

As several major economies turn inwards and invoke trade policies discriminating against particular products from developing countries, this study highlights the benefits of continued integration into global value chains for developing countries. Export-oriented agricultural manufacturing offers one path to achieve these goals. However well intentioned, policy actions that shift demand away from palm oil are likely to be detrimental for communities in producing regions. Reconciling the sector's past environmental–economic trade-offs through a shift to more sustainable production will likely lead to better development outcomes than a concerted shift away from the millions of farmers whose livelihoods depend on the controversial crop.

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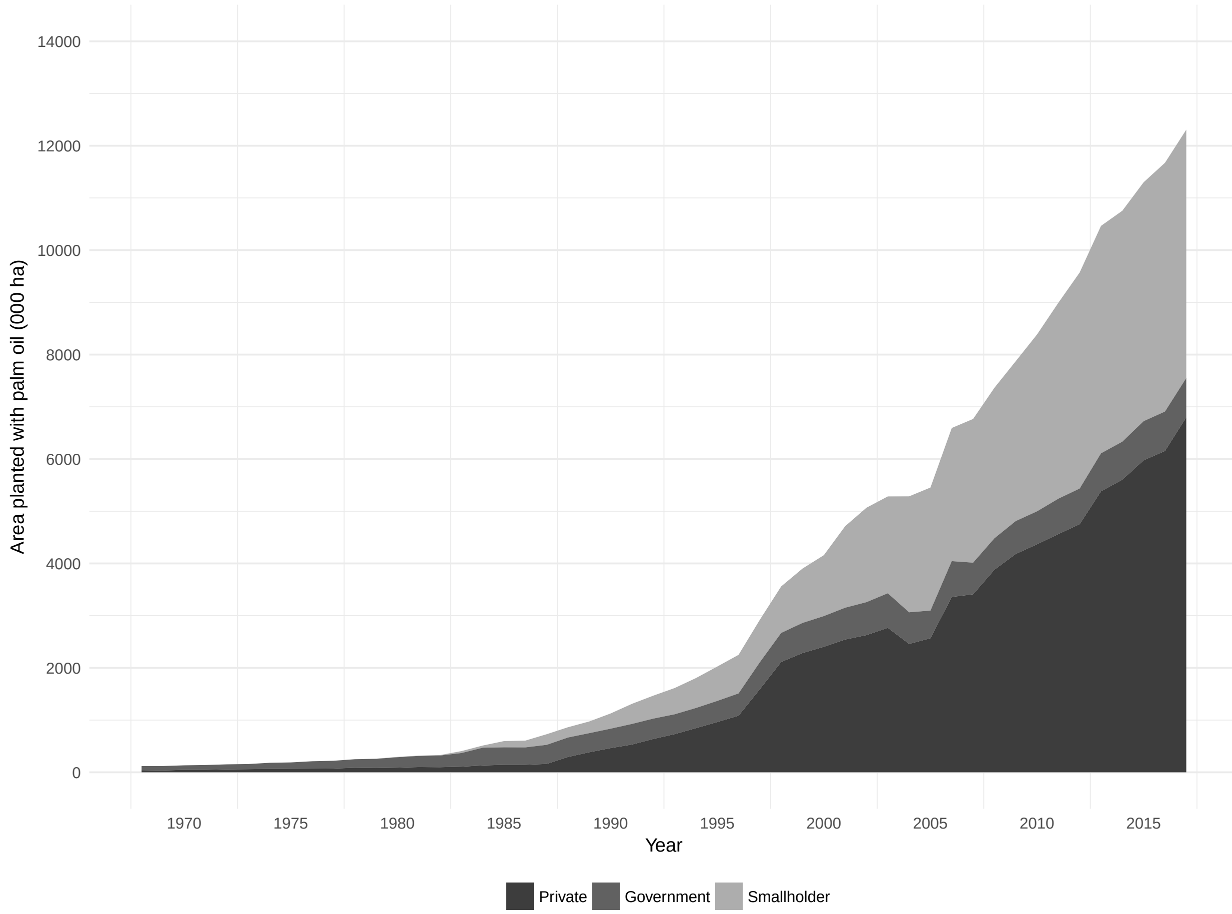
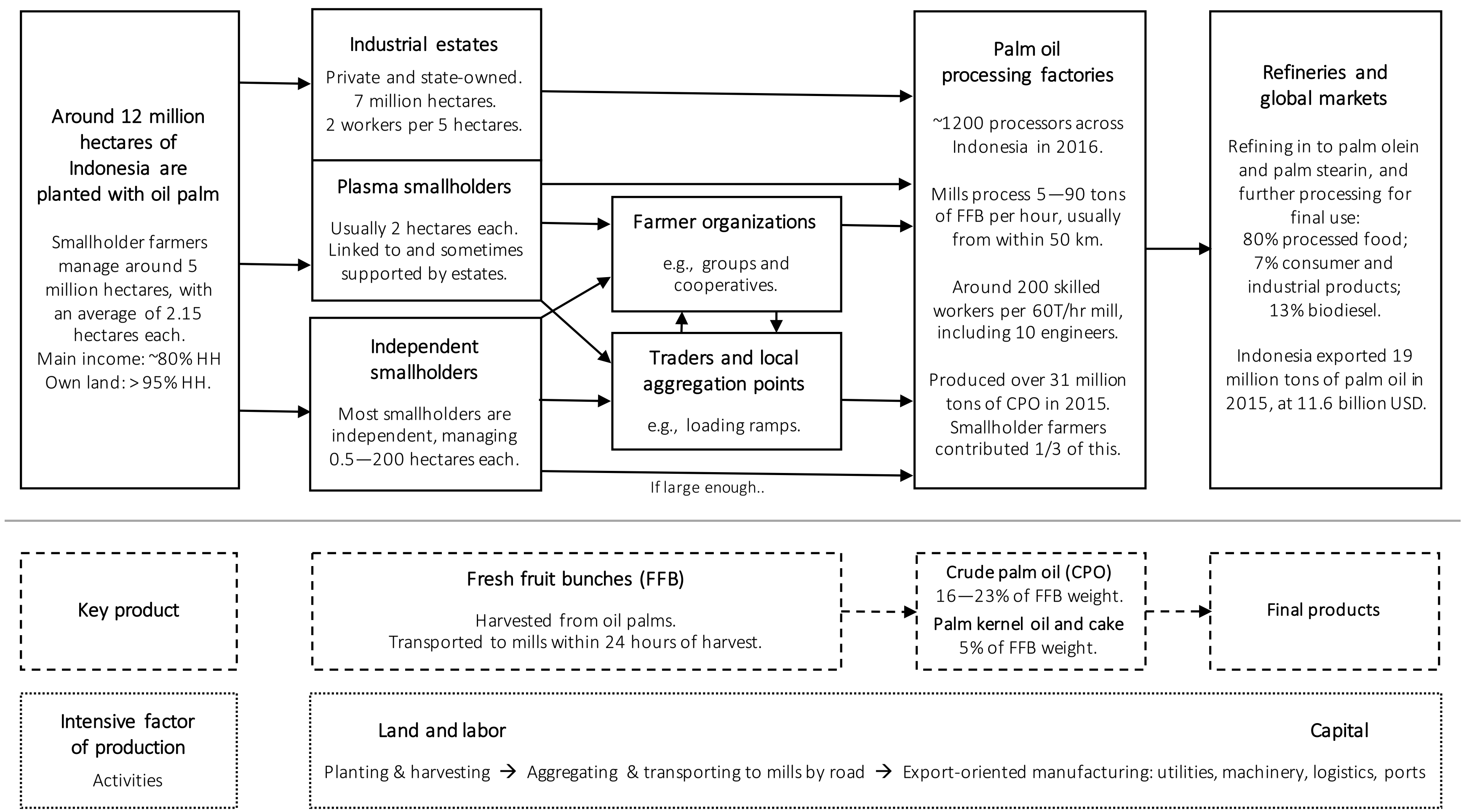
Figures

Figure 1: Indonesia's Palm Oil Expansion



Notes: Data are taken from the Tree Crop Statistics of Indonesia for Oil Palm yearbooks, produced annually by Badan Pusat Statistik (BPS) and the Department of Agriculture of the Government of Indonesia.

Figure 2: The Palm Oil Sector—A Stylized Overview

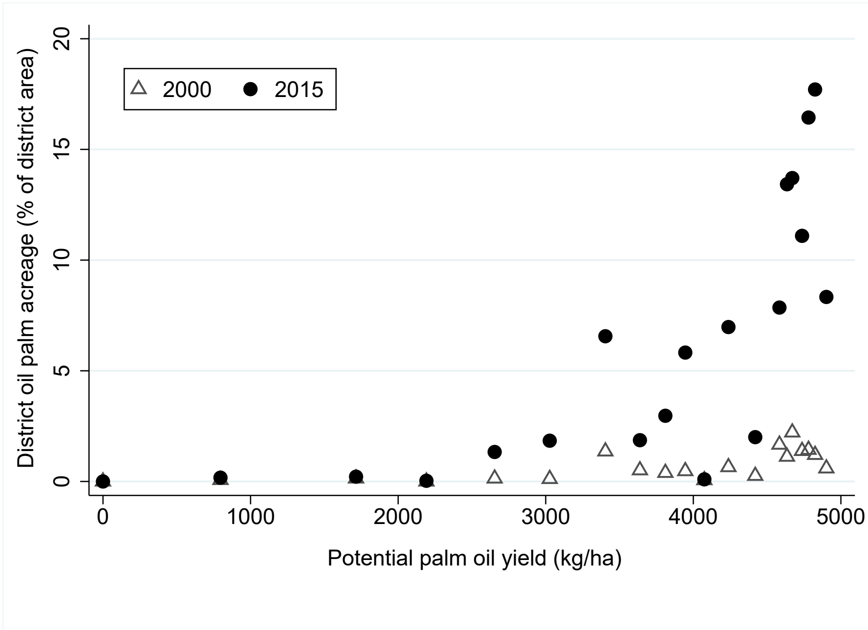


Notes: Author's own depiction. Figures are for Indonesia, from no earlier than 2013, and sourced from official government statistics, site visits, and personal discussions.

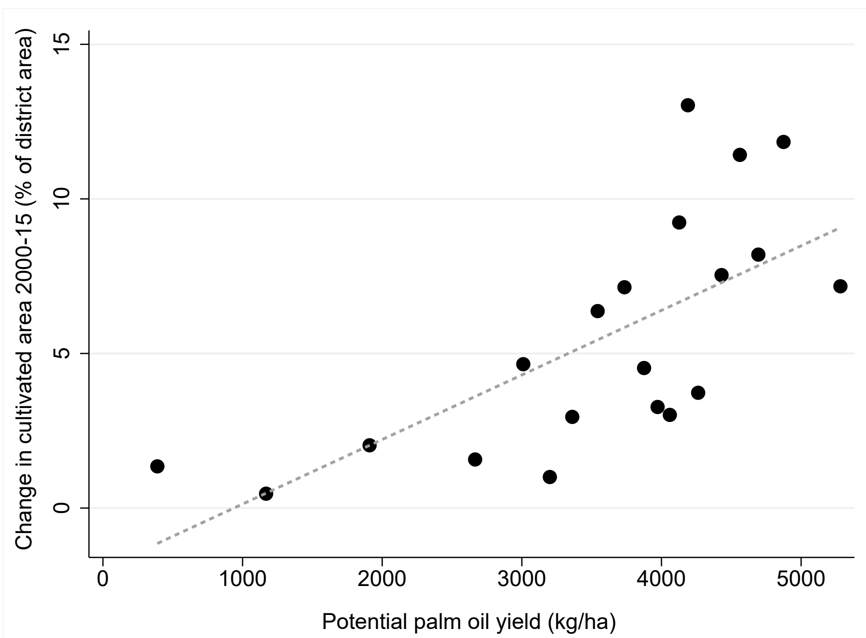
Figure 3: District Cultivation Intensity, 2009

Figure 4: First Stage

(a) District cultivated area in 2000 and 2015

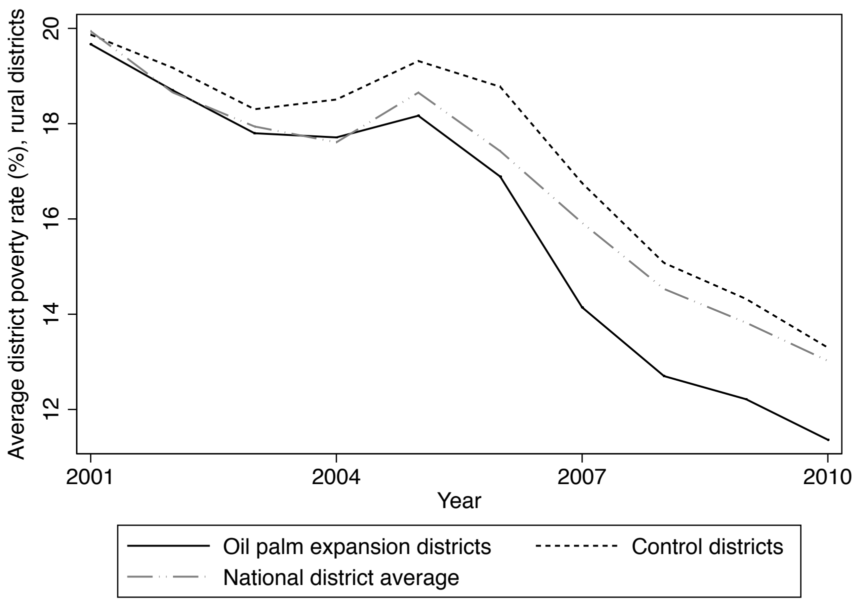


(b) Potential yields and areal expansion



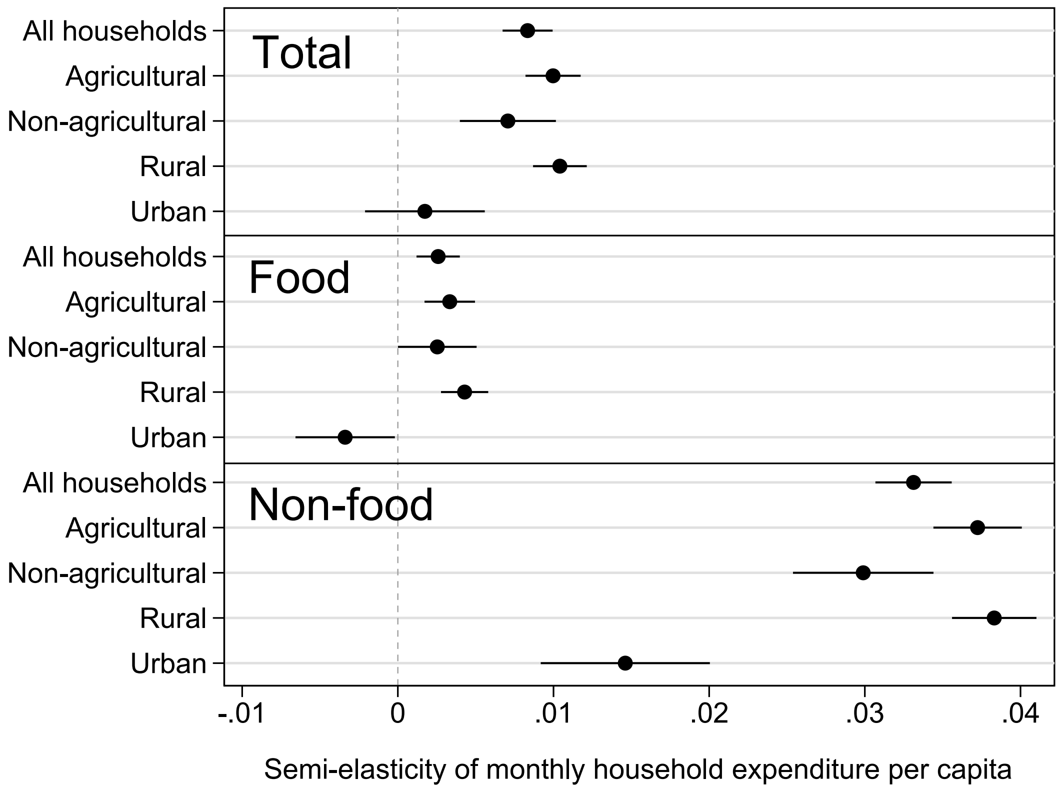
Notes: Panel A presents a binned scatter plot of district potential palm oil yield against the share of each district under cultivation for oil palm, split by year, to illustrate the increasing salience of the instrument after the demand shock. Panel B uses the change from 2000 to 2015 on the Y axis and includes the baseline initial conditions controls, showing the main first stage regression visually.

Figure 5: Expansion Districts Reduced Poverty Faster



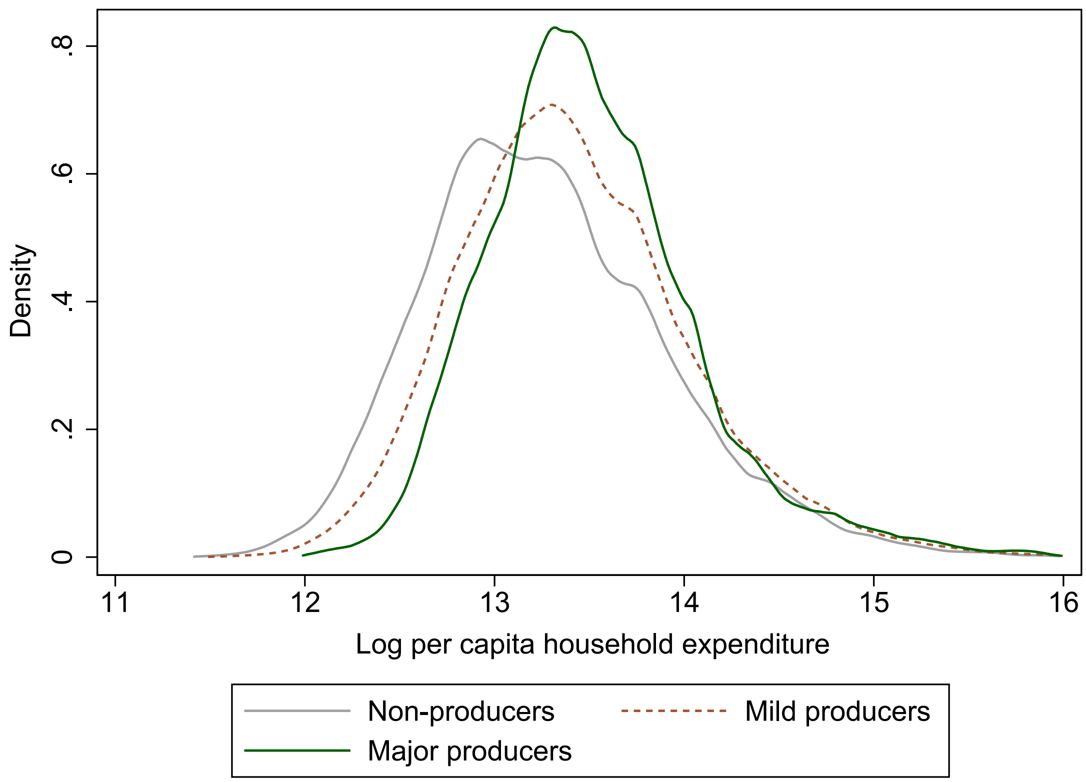
Notes: This figure is constructed using from the World Bank's DAPOER database for only the 2000s because I do not have BPS' district poverty rates or SUSENAS for all years from 2011–2015. All cities (*kotas*) and rural districts outside major palm oil cultivating regions are excluded. The national district average is for all districts nationwide, including cities and regions not producing much palm oil. Expansions are those with the largest expansion, specifically those increasing the share of district under cultivation by more than 17.5% from 2000–15, the top quarter of "expanders".

Figure 6: Consumption Impacts, By Type and Sector



Notes: This graph plots the estimated coefficients on oil palm land from my primary IV estimator using log per capita monthly household expenditure as a dependent variable for the full sample of SUSENAS households ("All households") and for sub-groups listed on the Y axis. Black lines indicate 95% confidence intervals. The full sample is repeat cross-section of all households in SUSENAS 2002 and 2015 linked to two-period balanced panel of all rural districts at 2000 boundaries excluding Java. District oil palm land is instrumented with district potential palm oil yield interacted with a post period indicator. District and year fixed effects, initial district conditions trends separately interacting 2000 log poverty, rural population shares, literacy rates, and sectoral employment shares with a post period dummy, and additional controls for household size, an urban/rural dummy, and sector fixed effects related to where households' primary income source included throughout. Urban/rural (sector) fixed effects are dropped when I examine effects by urban-rural households (across sectors).

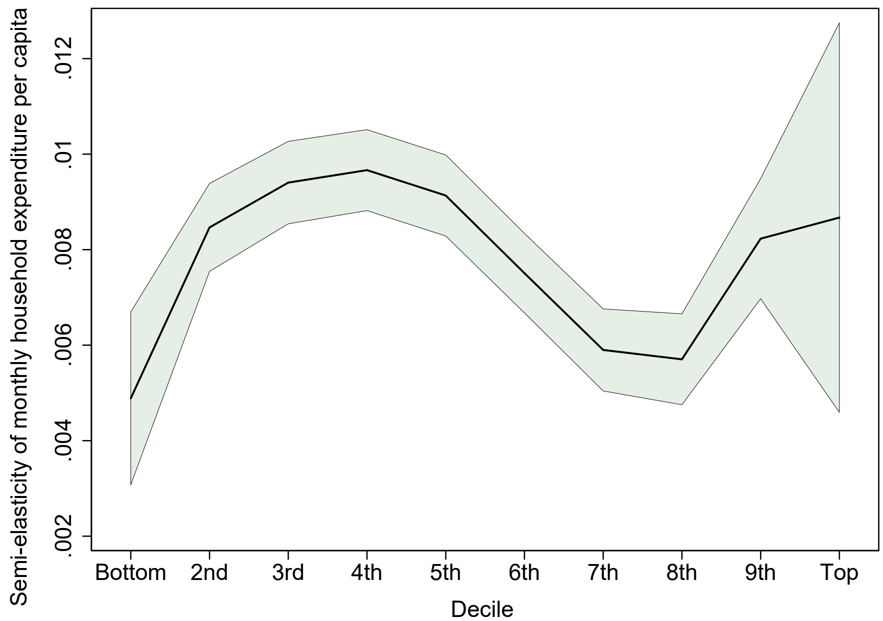
Figure 7: Consumption Distribution, 2015



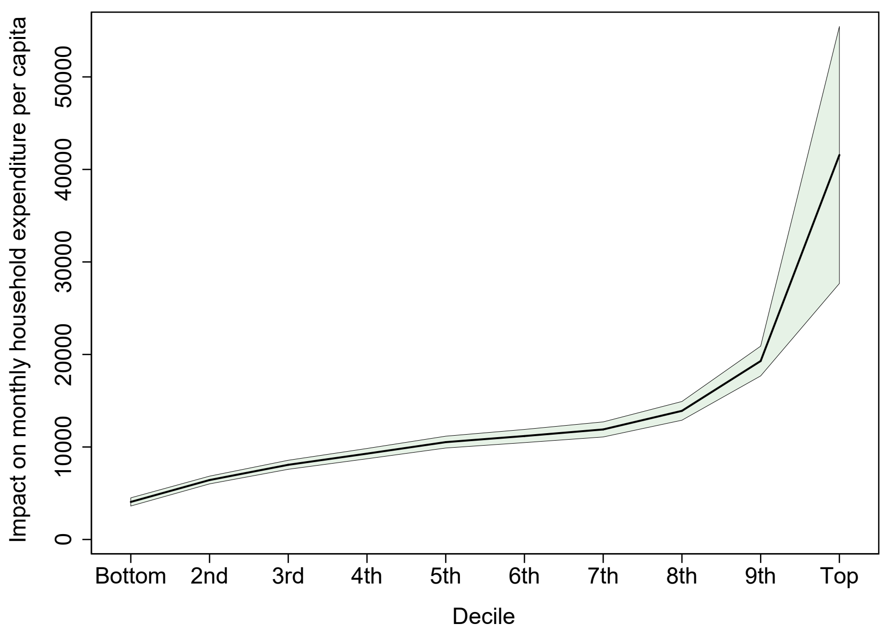
Notes: This graph plots kernel density estimates of log per capita household consumption in 2015 for households in rural districts not on Java that do not produce palm oil (gray solid), those that product only a little (red dash), and those that a major producers (green solid), defined as over 20% of the area under cultivation with oil palm.

Figure 8: Consumption Impacts By Decile

(a) Relative Gains

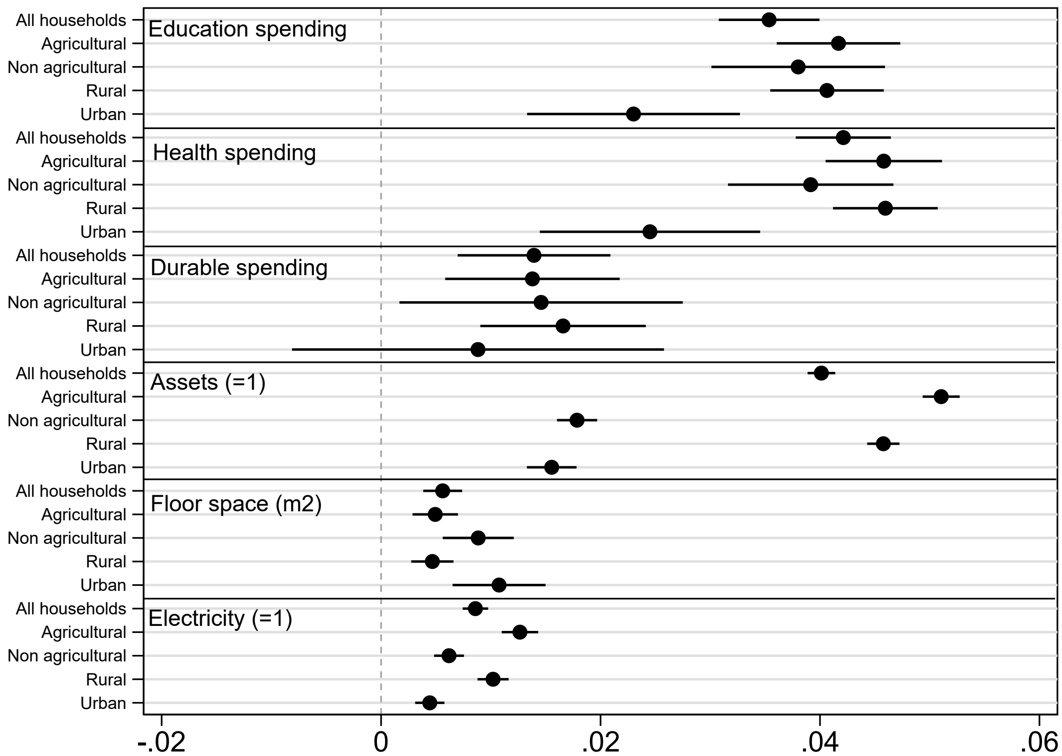


(b) Absolute Gains



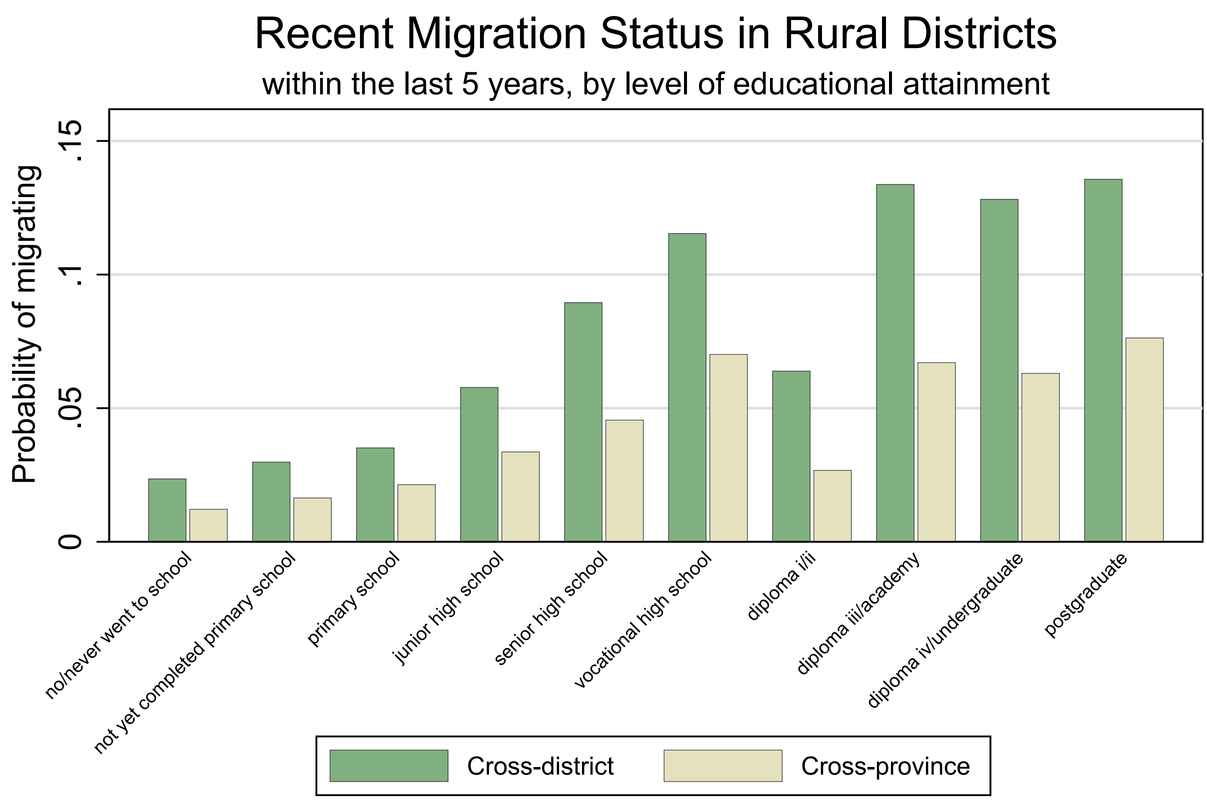
Notes: These graphs plot the estimated coefficients oil palm land from my primary IV estimator using [log] per capita monthly household expenditure as a dependent variable after dividing each district-year group of households up by decile of the consumption distribution. The black lines indicate 95% confidence intervals. District oil palm land is instrumented with district potential palm oil yield interacted with a post period indicator. District and year fixed effects, initial district conditions trends separately interacting 2000 log poverty, rural population shares, literacy rates, and sectoral employment shares with a post period dummy, and additional controls for household size, an urban/rural dummy, and sector fixed effects related to where households' primary income source are included throughout. The full sample is repeat cross-section of all households in SUSENAS 2002 and 2015 linked to two-period balanced panel of all rural districts at 2000 boundaries, excluding Java.

Figure 9: Impacts on Non-Food Expenditures and Assets



Notes: This graph plots the estimated coefficients on oil palm land from my primary IV estimator using log per capita monthly household expenditure as a dependent variable for the full sample of SUSENAS households ("All households") and for sub-groups listed on the Y axis. Black lines indicate 95% confidence intervals. The full sample is repeat cross-section of all households in SUSENAS 2002 and 2015 linked to two-period balanced panel of all rural districts at 2000 boundaries excluding Java. District oil palm land is instrumented with district potential palm oil yield interacted with a post period indicator. District and year fixed effects, initial district conditions trends separately interacting 2000 log poverty, rural population shares, literacy rates, and sectoral employment shares with a post period dummy, and additional controls for household size, an urban/rural dummy, and sector fixed effects related to where households' primary income source included throughout. Urban/rural (sector) fixed effects are dropped when I examine effects by urban-rural households (across sectors). Floor space is in logs.

Figure 10: Migration Status, By Education



Notes: This graph plots migration status reported in the 2010 Population Census by level of education. Data are for a restricted sample of all rural districts not on the island of Java, from the ten percent sample available publicly via IPUMS.

Tables

Table 1: Pre-expansion District Characteristics

Palm oil suitability (above/below median) Variable	Low Mean/SE	High Mean/SE	(1)-(2) t-test Difference
Poverty rate (%)	26.389 [1.315]	21.176 [1.325]	5.213***
Log per capita expenditure (IDR)	11.595 [0.026]	11.744 [0.022]	-0.148***
Over 15 literacy rate (%)	84.089 [1.515]	92.085 [0.493]	-7.996***
Agricultural employment share	0.651 [0.018]	0.632 [0.018]	0.019
Industrial employment share	0.087 [0.009]	0.105 [0.009]	-0.017
Rural population share (%)	85.352 [1.270]	81.099 [1.561]	4.253**
Population density	111.425 [13.856]	64.306 [7.378]	47.119***
Area (km^2)	10238.540 [1863.696]	14061.879 [1537.101]	-3823.338
Access to electricity (%)	60.245 [2.743]	64.640 [1.741]	-4.396
Oil palm villages share (%)	0.002 [0.001]	0.008 [0.001]	-0.006***
Palm oil production (tons)	7544 [2877]	46897 [13726]	-39400**
Ethnolinguistic fractionalization	0.496 [0.036]	0.591 [0.026]	-0.095**
Number of districts in 2015	1.975 [0.147]	1.905 [0.110]	0.069
N districts	79	96	

Notes: This table shows the observable difference in areas with high and low palm oil suitability, defined as being above or below the median agro-climatically attainable yield. Observations are districts in 2000 or the nearest feasible period. Data are taken from a variety of sources, detailed in Appendix 1.

Table 2: First-stage—Suitability and Areal Expansion

Dependent variable	Share of district area under cultivation for oil palm (%)				
Column	1	2	3	4	5
Post * suitability (kg/ha)	0.0021***	0.0022***	0.0019***	0.0023***	0.0020***
	(0.0004)	(0.0005)	(0.0005)	(0.0006)	(0.0004)
District and year fixed effects	✓	✓	✓	✓	✓
Baseline trends	✓	✓	✓	✓	✓
Cash crops trends		✓			
Additional trends			✓		
Lat-long polynomial trends				✓	
Poverty pre-trend					✓
Observations	334	334	326	334	288

Notes: Sample is a balanced panel of all rural districts in 2000 and 2015, at 2000 district boundaries, excluding cities and Java. Changes in samples size are due to data availability. Baseline trends separately interact 2000 log poverty, rural population shares, literacy rates, and sectoral employment shares with a post period indicator variable. Cash crops suitability includes similar interactions for cocoa, coffee, and teas. Additional trends include differential trends related to initial levels of ethnolinguistic fractionalization, the share of villages in each district with palm farmers, district production in tons, population density, and the percentage of households with access to electricity. Lat-long polynominal interacts each district's latitude and longitude, taken at its centroid, and the squared term of each, with the post period. Column 5 controls for log-changes in district poverty, and pre-period poverty is calculated from 1993–2002, when SUSENAS became district-representative and the Asian Financial Crisis had subsided. The sample is smaller because I reset the district definitions to 1993 boundaries to ensure comparability. Robust standard errors are in parentheses and clustered at the district level.

Table 3: Main Results—Regional Poverty and Household Consumption, 2000–2015

Dependent variable	District poverty rate (%)			Log expenditure (IDR)		
Estimator	OLS	IV	Reduced form	OLS	IV	Reduced form
Column	1	2	3	4	5	6
Oil palm land/district area (%)	-0.081**	-0.536***		0.001***	0.008***	
	(0.040)	(0.160)		(0.000)	(0.001)	
Post*suitability ('000 kg/ha)			-1.120***			0.018***
			(0.274)			(0.002)
Excluded F statistic		34.87			19908	
Observations	340	334	334	241349	237887	237887

Notes: Sample in Columns 1–3 is a two-period balanced panel of rural districts excluding Java at 2000 district boundaries, with any changes in samples size due to data availability. Sample in columns 4–6 are the household observations for the same districts, with identifying variation in oil palm expansion and suitability measured at the district level. IV estimates instrument district oil palm land share with district potential palm oil yield interacted with a post period indicator. District and year fixed effects and differential trends for initial poverty rates, rural population shares, literacy rates, and sectoral employment shares are included throughout. Household expenditure is measured in average, monthly, per capita terms. Household level estimates in columns 4–6 also include household size, an urban/rural dummy, and primary sector income fixed effects. Robust standard errors are in parentheses and clustered at the district level.

Table 4: Expansion onto Marginal Lands, 2000–2008

Dependent variable	District poverty rate (%)						
Estimator	OLS	IV	OLS	IV	OLS	OLS	OLS
Column	1	2	3	4	5	6	7
Oil palm land/district area (%)	-0.108**	-0.896***					
	(0.051)	(0.277)					
Oil palm area / farmland (%)			-0.011	-0.811***			
			(0.053)	(0.253)			
Farmland / district area (%)					-0.036*		
					(0.020)		
Oil palm area (000 ha)						-0.009**	
						(0.004)	
Farmland (000 ha)							-0.001***
							(0.000)
Excluded F statistic		26.280		25.911			
Observations	340	334	340	334	340	340	340

Notes: This table reports results from palm (SUSENAS) variation from 2000–2008 (2002–2010), half the period of my main results. It shows how point estimates are similar whether total district area or farmland is used as the denominator. Sample is a two-period balanced panel of all rural districts excluding Java at 2000 district boundaries, with any changes in samples size are due to data availability. Data on farmland are calculated by aggregating village farmland reported in the 2000 and 2008 village censuses up to the district level. IV estimates instrument the district oil palm land variable of interest with district potential palm oil yield interacted with a post period indicator. District and year fixed effects and differential trends for initial poverty rates, rural population shares, literacy rates, and sectoral employment shares are included throughout. Robust standard errors are in parentheses, clustered at the district level.

Table 5: Labor Productivity and Wages

Dependent variable	Output per worker		Log wages			
Sector	Agriculture	Manufacturing	All	Agriculture	Manufacturing	Services
Column	1	2	3	4	5	6
Oil palm land/district area (%)	1.600***	6.846***	0.039***	0.076**	0.026	-0.006
	(0.578)	(1.564)	(0.013)	(0.037)	(0.023)	(0.009)
Excluded F statistic	34.882	31.792	35.651	20.005	27.455	35.319
Observations	328	298	324	234	242	322

Notes: Sample is a two-period balanced panel of all rural districts excluding Java at 2000 district boundaries, with any changes in samples size are due to data availability. District oil palm land share is instrumented with district potential palm oil yield interacted with a post period indicator throughout. All estimates include district and year fixed effects and differential trends for initial poverty rates, rural population shares, literacy rates, and sectoral employment shares. Robust standard errors are in parentheses, clustered at the district level.

Table 6: Fiscal Linkages and Public Goods

Panel A: Fiscal outcomes (in logs)				
Level of government	District		Village	
Dependent variable	Revenue	Expenditure	Own source revenue	Expenditure
Column	1	2	3	4
Oil palm land/district area (%)	0.039***	0.043***	0.074***	0.054***
	(0.015)	(0.014)	(0.006)	(0.003)
Excluded F statistic	28.503	28.470	5104.267	7141.178
Observations	266	264	44699	70977
Panel B: Village public good provision (=1)				
Dependent variable	Clean cooking fuel	Improved road	Street light	Market
Column	5	6	7	8
Oil palm land/district area (%)	0.029***	0.002**	0.013***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Excluded F statistic	8447.504	8447.504	8447.504	8447.504
Observations	82349	82349	82349	82349

Notes: Sample is a two-period balanced panel of all rural districts excluding Java at 2000 district boundaries, with any changes in samples size due to data availability. Identifying variation in oil palm expansion and suitability is measured at the district level, and observations and outcomes at either the district or village level. District oil palm land share is instrumented with district potential palm oil yield interacted with a post period indicator throughout. All estimates include district and year fixed effects and differential trends for initial poverty rates, rural population shares, literacy rates, and sectoral employment shares, and village estimates include additional village level urban, coast, hilly terrain, and primary sector of income dummies. Robust standard errors are in parentheses. The sample used in Column 3 is smaller because some villages did not report OSR in one or both waves, which I consider missing at random.

Table 7: Descriptive Statistics—Migration

Sample		Estimation sample		All of Indonesia	
Year		2000	2010	2000	2010
Inter-district migrant (=1)					
Recent	Mean	0.066	0.046	0.059	0.045
	S.D	0.248	0.213	0.235	0.208
	N	5,736,837	7,153,617	18,078,905	21,312,179
Ever	Mean	0.201	0.266	0.183	0.204
	S.D	0.401	0.418	0.386	0.403
	N	5,738,985	7,166,922	18,078,099	21,349,932
Inter-province migrant (=1)					
Recent	Mean	0.031	0.025	0.03	0.024
	S.D	0.173	0.157	0.171	0.155
	N	5,736,837	7,152,617	18,076,205	21,312,179
Ever	Mean	0.123	0.14	0.107	0.124
	S.D	0.334	0.347	0.309	0.33
	N	5,738,985	7,166,922	18,078,099	21,349,932

Notes: Descriptive statistics for migration status reported in the 2000 and 2010 Population Censuses, for my sample of rural non-Java districts and for all of Indonesia. People report their district and province of residence five years ago and at birth in the Population Censuses. Here I use the ten percent sample from the Integrated Public Use Microdata Series (IPUMS).

Table 8: Population and Migration Impacts

Dependent variable	Log (population)	Lived in a different district..		Lived in a different province..	
		5 years ago (=1)	at birth (=1)	5 years ago (=1)	at birth (=1)
Column	1	2	3	4	5
Oil palm land/district area (%)	-0.0074	-0.00563***	-0.01580***	-0.00120***	-0.00284***
	(0.00860)	(0.00015)	(0.00015)	(0.00007)	(0.00013)
Excluded F statistic	27.5	569,058	570,362	569,678	569,678
Observations	270	9,523,094	9,533,206	9,535,015	9,535,015

Notes: Sample is a two-period balanced panel of all rural districts excluding Java at 2000 district boundaries, with any changes in samples size are due to data availability. Identifying variation in oil palm expansion and suitability is measured at the district level, and observations and outcomes at household level via IPUMS. District oil palm land share is instrumented with district potential palm oil yield interacted with a post period indicator throughout. All estimates include district and year fixed effects and differential trends for initial poverty rates, rural population shares, literacy rates, and sectoral employment shares. Robust standard errors are in parentheses, clustered at the district level.

Table 9: Environmental Impacts

Dependent variable	Forest loss, 2000–2016			Hotspot detections, 2000–2016		
Estimator	OLS	IV	RF	Poisson	IV Poisson	RF Poisson
Column	1	2	3	4	5	6
Δ Oil palm land/district area (%), 2000–15	0.008***	0.017***		0.032***	0.082***	
	(0.002)	(0.002)		(0.012)	(0.016)	
Suitability ('000 kg/ha)			0.032***			0.487***
			(0.004)			(0.152)
Observations	291	289	289	260	257	257

Notes: Sample is a cross-section of all rural districts excluding Java at 2000 district boundaries, with any changes in samples size are due to data availability. Forest loss is defined as the total number of pixels of tree cover loss since 2000 as a share of total district pixels. Hotspots are detections per district since 2000. IV estimates instrument the change in the share of each district planted with oil palm is instrumented with potential palm oil yield. All estimates include district and year fixed effects and differential trends for initial poverty rates, rural population shares, literacy rates, and sectoral employment shares. Robust standard errors are in parentheses, clustered at the district level.