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A household welfare perspective on the expansion of palm oil production in Indonesia

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Abstract: Palm oil production potentially affects environment, food security and rural development in Indonesia. However, there is little research on the welfare impacts of the production expansion. By using district level data on palm oil production and area planted and national household survey (SUSENAS), this paper studies the impact of the expansion of the palm oil production on household expenditure and health. Instrumental variable estimates exploit the historical production and district forest area as an exogenous source of variation. We find that smallholder production has a negative effect on household expenditure but this effect is not present among rural households. More, total cultivated area increases prevalence of asthma in Kalimantan. The results suggest that palm oil is not a panacea to increase rural welfare and that there is no evidence of positive spillover effects.

JEL Classification: I10, I30, O13, Q16, Q20

Key Words: Biofuels, health, household welfare, Indonesia, palm oil

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1 Introduction

The bulk of the worldwide expansion of oil palm plantations in recent decades has occurred in South-East Asia, and in particular in Indonesia, where the total land area devoted to palm oil has increased more than 2100 per cent since the early 1980s (Sheil et al., 2009). The welfare impacts of these plantations are being debated. There is evidence suggesting that oil palm plantations and other biofuel sources bring additional income for Indonesian households living in remote areas (see, for example, Peskett et al., 2007), and the proponents of palm oil claim that the industry has strong spillover effects. Also, the Government of Indonesia has subsidized smallholder production by providing credits and land. On the other hand, palm oil producers are blamed for extreme forest degradation, forest fires due to land clearing, and soaring food prices (see, for example, Naylor et al., 2007; Sheil et al., 2009; Rist et al., 2010). Despite being one of the most important topics in Indonesia, in terms of environmental policy, climate change and rural development, it is striking how little systematic empirical research exists on how households are affected by the expansion of palm oil production.

The objective of this paper is to evaluate the welfare implications of the expansion of palm oil production in Indonesia, primary focus being smallholder production. We argue that given the widely recognized negative externalities of palm oil production the producers should be able to demonstrate strong spillover effects for the society and therefore we will not limit the study exclusively to producers. Our approach is to study the impact of the increase in the area of oil palm plantations and the level of palm oil production, at the district level, on the welfare of the households and individuals located in these districts, regardless of whether they produce palm oil or not.[1]

The main welfare indicator used in this study is the household per capita expenditure.[2] In addition, we will study the impact of the expansion of palm oil production on the probability of a

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[1] Oil palm (elaeis guineensis) is the plant where as palm oil refers to the oil that is extracted from the palm: crude palm oil from the fruit and palm-kernel oil from the seed.

[2] Household expenditure is a standard welfare measure in poverty analysis. Spillover effects are commonly studied by looking at wages. However, we argue that wages and household expenditure are closely correlated (consistent information data is not available in the SUSENAS data).

household member reporting symptoms of asthma. This latter indicator was selected to evaluate the indirect costs of palm oil expansion. In particular, the conversion of tropical forests often involves forest fires, which in turn could have adverse effects on health, and particularly on breathing (see, for example, Osterman and Brauer, 2001). Palm oil production also involves toxic waste being released by refineries, and previous studies suggest that proximity to toxic waste correlates with increased levels of asthma (National Research Council 1991, p. 171). In addition, odours coming from these refineries might prove harmful to locals' health.

Forest fires are a frequent phenomenon in Indonesia. Although long dry spells related to the *El Niño* phenomenon typically worsen the situation, the prime cause of such fires is often land clearing for plantations, as burning the land is still regarded as the quickest and cheapest method. The study by Frankenberg et al. (2005) finds that the 1997 forest fires due to *El Niño* had a negative impact on the health of those individuals affected.[3] Also Osterman and Brauer (2001) report several studies that have documented the association between respiratory problems and both indoor and outdoor wood burning. However, the health impacts of the expansion of palm oil production have not yet been studied. Importantly, although land clearing using fire is now prohibited by law, smallholders continue to use this method due to a lack of machinery for alternative land clearing methods (Casson et al., 2007 in World Bank, 2010).

To our knowledge, this is the first study seeking to evaluate the costs and benefits of the expansion of palm oil production using large samples of survey data. The existing, albeit descriptive, studies have focused only on few villages at a time (see, for example, Feintrenie et al., 2010; Rist et al., 2010). Another descriptive study by Kessler et al., (2007) examines the socioeconomic impacts of the production of selected agricultural commodities, by comparing province-level outcomes in the mid 1990s with those in the early 2000s. The evidence regarding palm oil production in Indonesia is mixed; some indicators, such as employment, performed better than the national average, while others performed worse, particularly GDP per capita, poverty rates[4], and food security. Some descriptive village-level studies suggest a link between increased palm oil production and poverty reduction (see, for example Susila, 2004 in Rist et al., 2010), but this has not been verified in any larger scale study.

[3] In this study health status is measured as an ability to carry a heavy load, for example.
[4] HPI, Human Poverty Index. This index measures deprivations in life expectancy, education, and standard of living.

We employ annual data from the national household socioeconomic survey, SUSENAS, matched with district-level data on palm oil production and area planted. As an identification strategy we use the historical values of palm oil production and cultivated area as our main instrument, relying on the fact that palm oil production is most likely to expand in areas where the suitable conditions and knowledge are already present. To avoid losing data, the historical values are taken from the national agricultural village survey (PODES, *Potensi Desa* Agriculture Survey). In addition, we recognize the fact that not all districts are suitable for palm oil production. The relationship between palm oil production and forest degradation has been well documented. According to the FAO (2005), it is estimated that more than 56 percent of the expansion of oil palm plantations in Indonesia between 1990 and 2005 occurred at the expense of natural forest cover.[5] We use the district-level forest area prior to the study period as an alternative instrument for palm oil plantations/production. The underlying intuition is that forest area creates the potential for large oil palm plantations. The chosen instruments were best available but not without some limitations. However, we argue the results presented both by the fixed effects models and by the IV estimations will substantially bring forward the discussion on the welfare impacts of the expansion of palm oil production.

The results suggest that smallholder production in Indonesia as a whole, and also in the main production regions, Sumatra and Kalimantan, has a weak negative impact on household per capita expenditure but this effect is not present among households in rural areas. Therefore, the findings of this study indicate that there is no evidence of positive spillover effects put forward by the proponents of palm oil. With respect to health implications, smallholder area and production do not have an impact on the incidence of asthma either at the national level or in the main production regions. However, the total area and production of palm oil, i.e. including both smallholders and large plantations, increase asthma in West, South and East Kalimantan. The estimated impacts are rather small but, nevertheless material, given the scale of the expansion of the palm oil production in Indonesia.

[5] However, proponents of the palm oil industry claim that palm oil plantations are indeed forests, and that therefore the debate over deforestation is meaningless. Nonetheless, it is generally accepted that oil palm plantations do not provide the same degree of biodiversity and level of environmental services, such as carbon storage, as do natural forests. Palm oil proponents also claim that current plantations mostly use degraded forests. However, research suggests that even degraded forests retain more biodiversity than do plantations (Gillison and Liswanti, 1999; Maddox, 2007 in Sheil et al., 2009).

The rest of the paper is organized as follows. Section 2 provides background information on the expansion of palm oil production in Indonesia. Section 3 describes the data sources and descriptive statistics. Section 4 introduces the methodology and section 5 discusses the results. Section 6 concludes.

2 Background

In this section we first discuss the facts and trends of palm oil production internationally, and then focus on smallholder production in Indonesia, specifically. Finally, we discuss the costs and benefits related to palm oil production, and the relationship between palm oil production and deforestation.

2.1 Palm oil production: global and local trends

Oil palm is planted for commercial purposes in over 40 countries and accounts for almost 10 per cent of the world's permanent crop land (FAOSTAT). Indonesia is currently the largest producer of palm oil in the world (19,500 thousand tonnes in 2008/2009), as Indonesian production exceeded that of Malaysia in the mid-2000s. Indonesian palm oil production accounts for over 40 per cent of the world total production.[6]

The demand for palm oil has increased in the past two decades, initially for use in the chemical industry, food production and consumer goods. The soaring demand for biofuels explains the more recent boom. The largest importers of palm oil are China, India and the EU-27 bloc (USDA 2009). Palm oil has a high yield in terms of oil production; one hectare of oil palm produces 4000-5000 kg of oil, compared to 1000 kg for rapeseed, 800 kg for sunflower and 400 kg for soya bean and coconut. (Sheil et al., 2009, p. 11; 20). Currently, palm oil is the main source of vegetable oil, representing nearly 30 per cent of the world's vegetable oil production (World Bank 2010, p. 5). Besides being the world's leading exporters of palm oil, both Indonesia and Malaysia also have large domestic markets.

There has been an upward trend in the price of palm oil over the past two decades, albeit with a relatively high volatility. The world price of palm oil soared during the 2000s, peaking at

[6] http://www.pecad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/ (accessed 28 July 2011).

US$1,146 per tonne in March 2008. However, subsequently, during the global financial crises, the price of palm oil plummeted down to US$400 per tonne (Sheil et al., 2009, p. 19).

In Indonesia, palm oil is cultivated and produced by large private plantations (50 per cent of total production), smallholders (40 per cent), and large public plantations (10 per cent). The main production area is Sumatra. However, the plantations have recently been expanding eastwards; Kalimantan has become another major production area and Papua is expected to become the third major production area, due to its abundance of land (see, for example, Sheil et al., 2009; World Bank, 2010). In 2008, the region of Sumatra accounted for 78 per cent of Indonesian palm oil production, Kalimantan 18 per cent, Sulawesi 3, and Papua 1 per cent (Departementen Pertanian, 2009). During the period 1997-2007, the area devoted to oil palm cultivation grew fastest among smallholders, whose annual growth was 12 per cent, compared to 3 per cent for public plantations and 6.7 per cent for private plantations. Over this period, also the level of palm oil production grew fastest among smallholders. (World Bank, 2010).

According to the Government of Indonesia, the rapid growth in oil palm plantations will also continue in the future. Plantation areas are projected to expand from 7.4 million hectares in 2008 to 9.3 million hectares by 2015, a 25 per cent increase. Smallholders are expected to account for the largest share of this increase, although their annual growth rates will be smaller than in the past decades. As land constraint limits expansion in Sumatra, future growth is projected to occur predominantly in Kalimantan and Papua. There were 477 palm oil mills in Indonesia in 2006, of which majority were located in Sumatra. (World Bank, 2010.)

Palm oil contributed 1.5-2 per cent to Indonesian GDP in the early 2000s, rising to 4.5 per cent in the late 2000s (Barlow et al. 2003).[7] It is estimated that approximately half of crude palm oil production is exported, with palm oil accounting for approximately 6 per cent of the country's non-gas export earnings (World Bank, 2010). There are no accurate statistics on employment in the palm oil industry, but according to one estimate approximately 1.2 million labourers were employed in this industry in the early 2000s (Barlow et al., 2003)[8]. In terms of the monetary

[7] The late 2000s figure is taken from: http://www.istockanalyst.com/article/viewiStockNews/articleid/3660667, accessed on 18 September 2011.

[8] According to another estimate, oil palm cultivation accounts for 1.7 million to 3 million jobs in Indonesia, and the jobs in processing come on top of these figures. Moreover, the employment effects of smallholder plantations are

value of production, palm oil is in second place after rice of all agricultural products (FAOSTAT).

2.2 Smallholder production in Indonesia

Palm oil requires tropical conditions (an average annual precipitation of 1,780-2,280mm and a temperature range of 24-30°C), and an altitude less than 600 meters. Furthermore, palm oil thrives in disturbed forests and close to rivers, and is tolerant of various different soil types (Deasy, 1942; Sheil et al., 2009). Other factors that explain the expansion of oil palm plantations in Indonesia are infrastructure and population density, among others (Angelsen, 1995; Miyamoto, 2006).[9] Improved infrastructure increases land rent, and therefore increases the incentive to expand production. Various studies have also found that smallholders in the developing world respond to changes in relative prices (see for example Godoy, 1992). In Indonesia, there is also another specific factor, related to land rights and titles, which partly explains the conversion of forests into plantations. All forest in Indonesia is *de jure* owned by the state, but according to common law clearing the forest to agricultural land gives *usufruct* rights to this land (Angelsen, 1995; Sirait, 2009).

Smallholder palm oil production has expanded rapidly over the past decade. It is estimated that around 30 per cent of smallholder production is produced by individual farms and the remainder is by joint partnerships with large plantations (Barlow et al., 2003, p. 9). National data do not distinguish between independent smallholders and joint partnerships, but according to available estimates the recent growth can be largely attributed to independent smallholders (World Bank 2010, p. 4).[10]

One of the oldest arrangements for joint ventures between smallholders and large estates is the *Perkebunan Inti Rakyat* (PIR), which was introduced in the late 1970s by the transmigration programme.[11] This scheme provided an opportunity for companies to exploit both the large land

likely to be larger than those for large plantations. It is estimated that in smallholder plantations one person is employed in every 2 hectares, compared to approximately every 7 hectares in large plantations (World Bank, 2010).

[9] It is notable that these studies did not try to estimate any causal relationship, i.e. whether infrastructure causes the plantation expansions, or whether plantations provide the incentive to improve infrastructure.

[10] This is particularly the case in Sumatra, where the land constraint has restricted the expansion of large plantations (World Bank, 2010, p. 8).

[11] The aim of the transmigration programme was to reallocate people from the densely populated islands of Java and Bali to the less densely populated areas of Sumatra, Kalimantan and Papua. The programme was originally

areas conceded by the Government and the abundance of low-cost labour offered by migrants relocated from other areas in Indonesia (transmigrants).[12] In some cases, land acquisitions have been accused of offering inappropriate compensation. Other reported problems were dependence on a single crop, deteriorated food security and limited income sources during the 4-5 year unproductive period (Vermeulen and Goad, 2006; Feintrenie et al., 2010; World Bank, 2010).[13]

The PIR scheme was later followed by the Primary Cooperative Credit for Member's scheme, *Koperasi Kredit Primer untuk Anggota* (KKPA).[14] For example, the KKPA arrangement in Bungo district, in Jambi province in Sumatra, is based on a contract signed between the company, smallholders grouped in cooperatives, and banks, under the supervision of the Government. Smallholders allocate part of their land to the company, which plants, manages and harvests the crops. This part of the land forms the *nucleus* of the plantation, and landowners are paid back a share of the harvest revenue after deducting the management costs. On the other hand, the planting costs for land that remains with the smallholders, *plasma*, have to be paid by the smallholders. Smallholders organized as cooperatives have more autonomy under KKPA than under the traditional PIR arrangement although the bulk of the decision-making is still in the hands of the company. (Vermeulen and Goad, 2006; Feintrenie et al., 2010).

The advantages of the KPPA arrangement for the smallholders include access to improved seedlings and technical advice from the plantation manager. However, the drawbacks reported are similar to the PIR arrangement, such as high debt accumulated before the production period, disallowance of intercropping, dispute over land rights, and environmental damage.

2.3 Costs and benefits of palm oil production

Palm oil plantations and production may have relatively immediate impacts on return to labour and land. On the other hand, there may also be longer term impacts due to changes in land use, such as effects on food security and the ecosystem, among others. Oil palm has occupied large areas of land, possibly at the expense of other crops, and this might threaten food security. Moreover, the need for a quick processing after the harvest, as well as economies of scale in

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introduced during the Dutch colonial era and peaked during Suharto's regime. However, in the 2000s only a few families were relocated.

[12] Large companies could also work without smallholders, by purchasing the land and hiring workers.

[13] By comparison, the unproductive period for rubber is 6-7 years (Feintrenie et al., 2010).

[14] Generally the joint ventures are called the Nucleus Estate Smallholder (NES) system.

mills, necessitate mills having access to large areas of mono-cropped land, preventing local people from exercising mixed livelihood strategies (World Bank, 2010).

Palm oil production may have a different impact on household welfare in areas where land is abundant, as compared to those where it is constrained.[15] The PODES 2003 Agricultural Survey could provide some insight on this. PODES (*Potensi Desa*, Village Potential Statistics) is a census of all Indonesian villages surveyed by the Central Bureau of Statistics. PODES data on land use provides information on the hectares of rice fields that have been converted to other purposes during the past three years. We define no loss in rice fields if the reported area is zero, moderate loss represents villages where less than 100 hectares have been converted and heavy loss where more than 100 hectares of rice fields have been converted to other purposes. Table 1 below shows the village area of oil palm plantations according to these three categories. Descriptive evidence suggests that the relationship between rice field conversion and oil palm plantations varies across regions. In Sumatra, oil palm plantations are expanding onto converted rice fields, which could be indicative of a land constraint. By contrast, in Kalimantan the largest plantations are located in villages where no conversion of rice fields has taken place.

[Insert table 1 about here]

Air pollution due to land clearing and forest fires will also affect areas other than the precise burning place. The final distribution of air pollution depends on the direction and speed of the wind, but it is clear that the consequences are felt in a rather wide area (Frankenberg et al., 2005). In addition, crude palm oil production generates large amounts of waste. Refineries produce both liquid and solid waste as well as noxious odours and smoke pollution (McCarthy and Zen, 2010).

There are also several channels through which palm oil cultivation and production could benefit all households in the region. First, palm oil processing, such as mills and refineries, brings employment opportunities to the area, because the fresh fruit bunches must reach the mill within 24-48 hours of harvesting. Another possible channel is improved infrastructure that could benefit all households and industries in the region (see, for example World Bank 2010). And finally,

[15] Another important question relates to how palm oil affects off-farm employment opportunities. However, we do not have appropriate data to address this question.

spillover effects may be present. Proponents of palm oil defend the production expansion by promising increases in rural welfare and improved infrastructure. For example, the chairman of the Indonesia Palm Oil Association (GAPKI) argues that, "The development of oil palm plantations also plays a key role in rural development. - - With extraordinary multiplier effects, oil palm plantations in turn will become new centers of economic activities in rural areas. The development of road infrastructure provides access for isolated areas, allowing fast and dynamic economic activities".[16]

2.4 Deforestation

Although the relationship between oil palm plantations and deforestation has been documented in various sources (see, for example, FAO 2005), there is a degree of uncertainty related to the measures and definitions of deforestation (see, for example, Angelsen, 1995). First, the range of deforestation is wide, from a complete removal of tree cover to small changes in the ecological composition. Second, there is a difference between permanent and temporary conversions. Houghton (1993) estimates that conversion into plantations will normally result in a 30-60 per cent reduction in carbon stock in the vegetation, whereas conversion into pasture or permanently cultivated land involves a reduction of over 90 per cent. This estimate of the loss in carbon stock is similar to Tomich et al., (1998). In addition, oil palm plantations could also follow logging in which case palm oil is not the primary cause of deforestation (see also footnote 5).

A rather crude way to look at the relationship between oil palm plantations and deforestation in Indonesia is to use the data provided by the PODES 2003 survey. The section on land use contains a breakdown of forest land (*hutan*) in hectares converted to other uses over the past three years.[17] Using this information we construct three measures of deforestation: no deforestation, moderate deforestation and heavy deforestation, following Chomitz and Griffiths, 1996. The first category includes villages that report zero hectares of converted forests (90 per cent of villages surveyed), while the second category includes villages that report positive deforestation, but of less than 100 hectares (7.8 per cent), and, finally, the third category covers villages that report more than 100 hectares of converted forests (2.2 per cent). Comparing the

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[16] Jakarta Post, 12th February 2009 (available at http://www.thejakartapost.com/news/2009/12/02/palm-oil-economic-pillar-indonesia.html, accessed 15 October 2010).

[17] This variable is not a perfect measure of deforestation. First, the respondent might only have information on the village forest land, and not the state forest land. Second, the respondent might have included secondary forests or plantations in the forest category. Finally, it may be difficult to make precise area estimates.

total palm oil plantation area in these villages, we see that plantations tend to rise with increasing levels of forest conversion (see table 2 below). However, this observation cannot confirm whether oil palm plantations are causing the deforestation.

[Insert table 2 about here]

3 Data and descriptive statistics

To our knowledge, there are no available large-scale household surveys that include direct questions about households' engagement in oil palm production.[18] Therefore, in this study we use annual district level (*kabupaten*) palm oil data, together with the National Socioeconomic Survey, SUSENAS. This implies that we are not able to distinguish those households that are directly supported by the industry. On the other hand, the use of the large nationally representative household survey enables to study the presence of spillover effects. Because the SUSENAS is surveyed in the beginning of the year and the data on palm oil plantations and production reflect the situation at the end of the calendar year, we use the lagged values of the palm oil.

Palm oil data (both the area planted in hectares and production in tonnes)[19] come from the Indonesian Ministry of Agriculture, Directorate General of Estate Crops (*Departementen Pertanian, Direktorat Jenderal Bina Produksi Perkebunan*).[20] As stated earlier, oil palm is cultivated by smallholders, as well as by large public and private plantations. However, we primarily focus on smallholder production because smallholder data cover a longer time period (2003-2006) than do other available production data. Moreover, the smallholder data covers the whole area of Indonesia, including over 350 districts (using the 2002 definitions of districts). Following a decentralization process, a number of new districts were created in the 2000s. In this study, 2002 is therefore taken as a base year.

[18] The agricultural household survey, PATANAS might be an exception. However, the second round of the panel survey would only have been available only in late 2010, and moreover, the geographic coverage of this survey means that it would most likely only cover a few households engaged in palm oil production.
[19] Area data include immature, mature and damaged plantations.
[20] We consider that the quality of the data is largely satisfactory. However, we dropped two observations from the analysis that were likely outliers, i.e. had inconsistent growth in the production level compared to the previous year.

According to the national district-level data, the average area of smallholder plantations is 5,800 hectares and the average production is around 11,500 tonnes. Between 2003 and 2006, the average district smallholder oil palm plantation area in Indonesia increased by approximately 50 per cent, from 4,500 hectares to 6,800 hectares. However, approximately 67 per cent of the districts in Indonesia do not have any smallholder oil palm plantations. Restricting the sample to only those districts that do have smallholder plantations, the average district area of smallholder plantations is 18,100 hectares and the average production is around 41,400 tonnes, respectively. However, if we focus on the main production regions, in Sumatra only 28 per cent of the districts do not have any smallholder plantations, while the corresponding figure in Kalimantan is 31 per cent. The average district smallholder plantation area in those districts that do have smallholder plantations is 22,600 hectares in Sumatra and 11,000 hectares in Kalimantan. Table 3 below presents summary statistics on smallholder area and smallholder production for all districts in Sumatran and Kalimantan irrespective of whether the districts have smallholder plantations.

[Insert table 3 about here]

Nationwide, smallholder oil palm plantations represent, on average, one per cent of the district land area, but there are large differences across the regions. In Sumatra, there are districts where up to 15 per cent of the area is covered by smallholder plantations, while in Kalimantan, the proportion varies from 0 to 5 per cent.

In addition to the smallholder data we employ the complete data (both smallholders and large plantations) for selected provinces in Kalimantan.[21] The area data cover the provinces of West Kalimantan, South Kalimantan and East Kalimantan (but not Central Kalimantan), and the production data cover the provinces of West Kalimantan and South Kalimantan (but not Central Kalimantan and East Kalimantan). However, the production data is inadequate for robust analysis and therefore only the effect of total palm oil area on household welfare is investigated, see section 5.2 for further discussion. This data cover the time period 2004-2007, although data for the year 2004 is only available for West Kalimantan.[22] In these provinces the average district area devoted for oil palm plantations is 34,000 hectares when focusing only on those districts

[21] Area data cover immature, mature and damaged plantations.
[22] Due to the inability to get comparable household expenditure data for the year 2008, the year 2007 is only used in health specifications.

that do have plantations. Table 4 below presents summary statistics on total area of plantations for selected provinces in Kalimantan irrespective of whether the districts have oil palm plantations.

[Insert table 4 about here]

The annually implemented SUSENAS survey is a nationally representative household survey. Each year, in late February or early March, a new set of roughly 200,000 households are interviewed as part of the core of the national socio-economic census (SUSENAS). The dataset includes results from a small consumption module, consisting of 15 food items and 8 non-food items, that combines purchased and own-produced items. Household per capita expenditure is deflated to 2007 prices using the consumer price index of the province capital. In addition there is data on household characteristics, such as education and health status of the household members, and housing conditions. The average log monthly per capita expenditure is 12.57 over the surveys, equivalent of 360,000 Indonesian rupiahs, or US$40. Very few household members report symptoms of asthma; only 1.7 per cent of the individuals aged 10 and above reported suffering from asthma over the preceding month. The summary statistics for the three dependent variables are presented in table 5 below.

[Insert table 5 about here]

In addition to the core datasets, two other data sets are employed in order to construct the instruments for the IV estimation. First, PODES data is used to construct a historical measure of palm oil production in a district. The PODES data come from a survey of over 65,000 villages throughout Indonesia, which rotates themes such as agriculture, economic and population. The 2003 PODES Agriculture Survey includes a section on village-level plantation crop production, and both the area and production of the five most important plantation crops are listed here.[23] It is notable that the 2003 PODES survey was implemented in 2002 and therefore the production data refer to the year 2002. This is important as our study period starts in 2003. We aggregate palm oil production levels and oil palm plantation areas in all villages in a district, in order to

[23] As there are not too many plantation crops our judgement is that if oil palm is not listed among the five most important crops then the cultivation of oil palm is likely to be only a marginal activity.

construct a historical district-level measure of palm oil production and plantation.[24] Importantly, the 2003 PODES survey covers the whole geographic area of Indonesia.

Satellite data on district forest cover is used to construct an alternative instrument for oil palm plantations and palm oil production. The proportion of district area covered by forest was provided by the Geographic Information Science Center of Excellence, South Dakota State University (see Broich et al., 2010 for further information). The district area in square kilometres was then employed in order to calculate the forest area of a district in 2000. As discussed earlier, large areas of forest have been converted into oil palm plantations and, therefore, district forest area prior to the study period is likely to be a good source of exogenous variation in palm oil production.[25] Because the forest area is calculated prior to the study period, the possible direct correlation between household welfare and forest cover is eliminated.

Finally, we have monthly rainfall data covering the period of 1951-2007. This data is taken from two sources. Data for the period 1951-1998 was provided by Kirono et al. (1999), while that for the period of 1999-2007 come from the Indonesian Meteorological Agency (BMG). These data are used in robustness checks in sections 5.1 and 5.2.

4 Empirical strategy and identification

Using the time series oil palm plantation and palm oil production data as well as SUSENAS surveys, the impact of palm oil production expansion may be expressed as follows:

$$I_{idt} = \beta_1 + \beta_2 PO_{dt-1} + \beta_3 X_{idt} + D + \mu_{pt} + T + \varepsilon_{idt}, \qquad (1)$$

[24] It is not stated specifically whether the area and production refer to smallholders or to total production. However, as the village head would probably not have access to data on area and production for private companies, it is therefore likely that this measure best refers to smallholders.

[25] Strictly speaking, large forest areas could also be used for other plantation crops, such as rubber, and therefore the effect of this IV specification could be a general plantation crop effect, not only specific to palm oil. However, no other plantation crop has expanded as aggressively as oil palm.

where I_{idt} is the selected impact (log per capita household expenditure or health indicator) of household/individual i living in district d in year t, PO is the level of palm oil production in tonnes or the area of oil palm plantations in hectares in district d at time $t-1$, D a district fixed effect, μ_{pt} a province-year interaction term to control for any annual province-level shock affecting household expenditure or health, T year fixed effect, and ε_{idt} is the error term, clustered at districts. Because the SUSENAS survey takes place in the beginning of the year, while values for oil palm plantations and palm oil production levels reflect the situation at the end of the calendar year, we use the lagged values of the palm oil. X is a vector of household or individual characteristics such as household head's education level, age, gender, industry category, and occupation type, as well as household size in the household expenditure specifications. In the health specification we control for the respondent's gender, age, education and industry category as well as some household characteristics related to the housing conditions that could also affect health status, such as dummy variables indicating whether household has its own toilet or uses tap water, or whether the dwelling is owned by household. In addition, we include a dummy for rural areas in both specifications. In health specification I use standard linear probability model (LPM).

The OLS specifications serve as benchmark estimates but could nonetheless be biased. First, there could be omitted variables that are correlated both with palm oil production and household welfare. The district fixed effects control all time-invariant factors that affect both household welfare and palm oil production, such as soil type. However, there could still remain time-varying factors that are omitted from the regression and resulting, therefore, in biased estimates, such as infrastructure and rainfall, among others.[26] Also some time-invariant factors such as soil type could have both level and trend affects.[27] Second, palm oil production could be endogenous in this context. Palm oil production requires large and expensive investments, such as roads and mills, and therefore districts with high average incomes are more likely to be engaged in palm oil production. However, it is notable that the dependent variable is at household or individual level

[26] However, it is likely that the province-year interaction term captures the effects to some extent. Nevertheless, in sections 5.1 and 5.2 we implement some robustness checks where we include rainfall as an additional control.

[27] Strictly speaking extensive cultivation could exhaust the land and alter the soil type but in this paper I assume that soil type is time-invariant during the study period. This assumption is reasonable given the relatively short time period.

and palm oil is measured at district level. Therefore to the extent that there is any reverse causality, it is likely to be weak. Third, there could be positive sorting; that is palm oil could attract wealthier households into the region.[28] And finally, both oil palm plantations and total production are likely measured with some error.

Health status, in this case the probability of household member reporting symptoms of asthma, is measured at individual level. Therefore the problem of reverse causality is less likely to be a problem in the health specification compared to the expenditure specification. However, there could still be omitted factors correlated both with the palm oil production and health status.

One method that addresses all four possible problems related to the OLS estimation is the Instrumental variable approach, IV. Finding instruments for palm oil is, however, not straightforward. Many factors determining palm oil production (including rainfall, among others) could also be correlated with household welfare thorough other mechanisms than palm oil (say rice production). According to the land suitability assessments the requirements for cultivation of oil palm are not exclusive, in the sense that these areas are typically also suitable for rubber cultivation, among other crops (Ritung et al., 2007). As regards other geographical variables, altitude could be a potential instrument given that oil palm thrives at altitudes below 600 metres (see section 2.2). However, altitude did not have enough power as an instrument.[29]

In order to implement the IV estimation, we will construct a separate prediction model to predict the production of palm oil in a district, and then use the predicted values as instruments for actual values in the two-stage least squares estimation.[30] In the prediction model we will exploit the fact that not all districts are suitable for oil palm plantations. The principal idea is to include variables exogenous to household welfare in the prediction model, in order to generate exogenous

[28] Future research could address the relationship between palm oil production and migration. However, by controlling for the education level we are able to reduce the bias related to possible sorting.

[29] One plausible explanation for this may be that the relationship between the district altitude, on the one hand, and its palm oil production levels and oil palm plantations, on the other, is weak, in the sense that there is no clear cut-off point, but rather a gradual decline as altitude increases. Another possible explanation is that the data used in this study to calculate the proportion of district area that falls into four different elevation categories is not optimal. The 2003 PODES village survey has information on the altitude of each village, which I then used to calculate the proportion of villages in each elevation category in the given district. This method relies on the assumption that the villages are of equal size and spread evenly across the district.

[30] Duflo and Pande (2007) use river gradient in order to predict the number of dams per district and then use the predicted number of dams in the district as an instrument for actual number of dams. Another paper that that use similar estimation strategy, that is, using predicted values as instrument for actual values, is by Saiz (2007).

variation in the predicted values. We have identified two potential sources of exogenous variation in the palm oil production and the relative merits of the instruments are discussed as follows.

First, lagged values of palm oil production could predict future production. The use of lagged values of an endogenous variable as an instrument is a standard method in the literature (see, for example, Jalan and Ravallion, 1999). The use of lagged values as instruments is based on the idea that areas suitable for oil palm cultivation are also likely to have high production levels in the future. Oil palm plantations also require special knowledge and skills, providing another reason why lagged values have good prediction power. In order to avoid losing any data, the historical values of palm oil production are taken from the 2003 PODES survey.[31] This agricultural survey contains village-level information on the planted area of oil palm and level of production of palm oil throughout Indonesia. We aggregate these village-level data at the district level, which provides an approximate measure of district level data in 2002. These district-level measures of oil palm plantations and palm oil production in 2002 are time-invariant variables. Therefore they are interacted with predicted province-level palm oil area or production in order to predict the area of plantations and palm oil production in each district, this method to some extent follows the method by Duflo and Pande (2007):

$$PO_{dt} = \alpha_1 + \alpha_2\left(PO2002_d * \overline{PO}_{pt}\right) + D + \mu_{pt} + T + \varepsilon_{dpt,} \qquad (2)$$

where PO_{dt} is the palm oil production level (in tonnes) or oil palm cultivated area in hectares in district d at time t, $PO2002$ is the district palm oil measure in 2002, and $\overline{PO_{pt}}$ is the predicted palm oil production in province p at time t. This is constructed by multiplying the total production of palm oil in Indonesia in the given year with the proportion of production in the given province in 2003. In the area specification we use the predicted value of oil palm plantation, obtained by multiplying the total oil palm plantation area in Indonesia in the given year by the proportion of plantations in the given province in 2003. The use of predicted, rather

[31] The 2003Podes agricultural data uses 2002 data.

than actual values of production levels and plantation areas, ensures that the palm oil production is exogenous with the district palm oil production. D is the district fixed effect and T year fixed effect and μ_{pt} is the province-year interaction term included to account for any annual shocks that are common across districts in a province and that might affect palm oil production.

As expected, historical areas of plantations and levels of production are positively associated with current plantations and production. This finding reflects the fact that palm oil is expanding most strongly in areas that have been identified as suitable areas for planting oil palm and where there is appropriate knowledge and knowhow easily available. The F-test for historical palm oil variable interacted with predicted province measure of palm oil is 7.45-10.47, depending on the specification, implying that the chosen instruments have sufficient prediction power (see table 6 below). Prediction model for total cultivated areas in Kalimantan using historical measures as an instrument is presented in the Appendix, column 1 in table A1.

[Insert table 6 about here]

There are some deficiencies related to this IV approach, however, as the historical values of plantation areas and production levels may still be correlated with the error term. If there are omitted variables that are serially correlated, the use of historical values might introduce bias into the IV estimates, and thus undermine the validity of the instrument (see, for example, Angrist and Krueger, 2001).[32] Therefore, we will also introduce an alternative instrument, district forest cover. As discussed earlier, the conversion of natural forest into oil palm plantations has been widely documented. However, the presence of forests could affect household expenditure and welfare in various ways, such as by providing firewood and other forestry products (such as natural rubber), or by providing hunting opportunities, among others (Angelsen, 1995). Therefore, to ensure that the correlation between forest area and household welfare realizes through palm oil, and not through these other mechanisms, data on forest area prior to the study period is used. We have used satellite data on the district forest cover (per cent) for the year 2000, together with data on district area (square kilometres), to calculate the district forest area in 2000. The district forest area may be used as an indicator of the opportunity to plant oil palm that is exogenous to household characteristics such as knowledge and income.

[32] A potential serially correlated omitted variable is infrastructure.

Despite of these advantages, there are some disadvantages related to this instrument. First, data on forest cover are only available for Sumatra and Kalimantan. However, as Sumatra and Kalimantan are the main production regions, and together account for approximately 95 per cent of the national production we argue that this limitation is unlikely to bias the results to any significant extent. Second, forest data used in this study is not pure, in that it also covers mature plantations, which introduces some noise to the forest measure. The satellite data employ a definition of forest as areas where there is a tree canopy exceeding 25 per cent coverage, and greater than five meters in height. Unfortunately, when using this definition, it is not possible to distinguish between natural forest and mature oil palm plantations. However, we argue that this is not a major issue, given that oil palm plantations are not a major contributor to the total forest area. Province-level data shows that the proportion of oil palm plantations out of total province forest cover is, on average, 11.2 per cent in Sumatra and 1.4 per cent in Kalimantan.

The prediction model using the forest area as an instrument can be expressed as follows:

$$PO_{dt} = \alpha_3 + \alpha_4(forest * \overline{PO}_{pt}) + \alpha_5(forest * t_t) + D + \mu_{pt} + T + \varepsilon_{dpt}, \qquad (3)$$

where PO_{dt} is the palm oil production (in tonnes) or plantation area in hectares in district d at time t, $forest$ is the forest area in a district (in square kilometers) in year 2000, $\overline{PO}_{pt}$ is the predicted palm oil production or palm oil plantation area in province p at time t as explained earlier. The interaction term between the forest area and year dummies allows for a varying impact of forest area on palm oil. This is to say, that the conversion rate could be different across the years. D represents district fixed effects, T year dummies while μ_{pt} is the province-year interaction term as earlier.

Table 7 below shows that, as expected, forest area in 2000 is positively correlated with palm oil area and production in subsequent years. The corresponding F-test is approximately 11.5 in the oil palm area specification and 17 in the production specification. Prediction model for total area in Kalimantan using district forest area as an instrument is presented in the Appendix, column 2 in table A1.

[Insert table 7 about here]

We will estimate equations (2) and (3) in order to predict the cultivated area of oil palm and the level of production in each district. The predicted values will then be used as instruments for actual values. The first stage regression for the specification with historical values of palm oil used as an instrument is as follows:

$$PO_{idt} = \theta_1 + \theta_2 \widetilde{PO}1_{dt} + \theta_3 X_{idt} + D + T + \varepsilon_{idt}. \quad (4)$$

And the first stage regression using forest area as an exogenous variation in palm oil is as follows:

$$PO_{idt} = \theta_1 + \theta_2 \widetilde{PO}2_{dt} + \theta_3 X_{idt} + D + T + \varepsilon_{idt}. \quad (5)$$

Finally we will estimate equation (1) with 2SLS, using fitted values from the first stage regressions, (4) and (5). In all regressions standard errors are clustered on a district level. [33]

5 Empirical results

5.1 Smallholder area and production

Per capita expenditure. The first set of results relates to the impact of smallholder oil palm plantation area and smallholder palm oil production on household per capita expenditure. We first discuss the results for smallholder area. Estimates derived with the OLS suggest that smallholder area is negatively associated with household expenditure in Indonesia as a whole but

[33] No attempt was made to use sample weights.

the estimated coefficient is not statistically significant at the conventional levels (see column 1 in table A2 in Appendix). The IV estimates give very similar results to the OLS ones (see column 2 in table A2). There is no notable difference when restricting the sample to rural households only (see columns 3 and 4 of the table A2).

OLS regressions give rather similar results when restricting the sample to the main production regions, Sumatra and Kalimantan. The summary of the main results for Sumatra and Kalimantan is presented in table 9 below (for further details, see tables A4 and A5 in Appendix). The estimated effect of smallholder area on per capita expenditure is negative but statistically insignificant at the conventional levels. However, in this sample the IV estimate using historical forest area as an instrument indicates a negative effect (see column 3 in table A4). The estimated effect suggest that a thousand hectares increase in the district-level smallholder plantations decreases household expenditure by 0.45 of a percentage point and the estimated effect is marginally statistically significant at the 10% level. The corresponding elasticity is 0.066.[34] The average size of the district smallholder area in Sumatra and Kalimantan is 13,300 hectares over the survey period, so an increase of thousand hectares is equal to six percent of the average area. It is notable that the IV using historical plantations as an instrument reveal a negative but statistically insignificant effect (see column 2 of table A4). In both IV estimations the first stage F-test is acceptable albeit higher in the specification when using historical values of plantation area as an instrument. Moreover, the IV estimation using historical forest cover as an instrument suggest a weak negative impact of smallholder area also in the rural areas. However, now the first stage F-test is low (4.18) and we therefore consider it is reasonable to conclude that the negative impact is not present among households living in rural areas (see table A5 in the Appendix).

There could be several factors underlying the negative relationship. For example, oil palm plantations may have been developed at the expense of crucial subsistence crops. There is also evidence of unfair agreements between landholders and palm oil producing companies, resulting in high debt burdens for farmers.

[34] The elasticity is calculated using the form: $\beta * \bar{x}$.

Next we will discuss the results for smallholder production. Using the data for Indonesia as a whole, OLS estimation results suggest that, similarly to smallholder plantation area, smallholder production has a negative but statistically insignificant impact on household per capita expenditure (see table A3 in Appendix, column 1). However, the IV estimate suggest a weak negative impact of smallholder production in all Indonesia, but again, the negative impact is not present among rural households (see table A3 in the appendix, columns 2 and 4). The estimated effect implies that a thousand tonnes increase in the district-level smallholder production decreases household per capita expenditure by 0.09 per cent, while the corresponding elasticity is -0.01. It is notable that given the wide geographic area of Indonesia and the heterogeneity of livelihood strategies, as well as wide differences in standards of living across the country, pooling the nationwide data might cause problems in terms of comparability.

Similar results are obtained when restricting the sample to Sumatra and Kalimantan only. OLS regressions suggest a negative, but statistically insignificant, impact of smallholder production on household per capita expenditure for households in Sumatra and Kalimantan (table A6 in Appendix, column 1). However, now both IV estimates suggest that smallholder production decreases household expenditure in Sumatra and Kalimantan and the estimates are marginally statistically significant at the 10% level (see Appendix table A6, columns 2 and 3). The estimated effects imply that a thousand tonnes increase in the district-level smallholder production decreases household per capita expenditure by 0.09 per cent (using historical production from PODES 2003 as an instrument) or 0.24 per cent (using district forest area as an instrument).[35] The corresponding elasticities are -0.024 and -0.068 respectively. Although these elasticities are rather low, the scale of the expansion suggests that the economic impact is moderate. For example, in Sumatra and Kalimantan the average district-level smallholder production increased around 16,000 tonnes between 2003 and 2006 (from around 19,600 tonnes to around 35,500 tonnes). Employing the estimated effects above, household per capita expenditure fell approximately 1.44 per cent (using historical production from PODES 2003 as an instrument) or 3.84 per cent (using district forest area as an instrument) over the study period resulting from the increase in the level of district smallholder production. Interestingly,

[35] The average level of district smallholder production in Sumatra and Kalimantan is around 26,000 tonnes over the survey period and therefore 1000 tonnes are equal to approximately four percent.

restricting the sample to rural households only, the negative effect is no longer statistically significant (see table A7 in the Appendix).

Finally, it is notable that generally the coefficients in the IV regressions are larger in absolute terms than the OLS equivalents suggesting that the OLS coefficients are biased upwards. This is in agreement with prior expectations because, as discussed earlier, palm oil production requires large investments and knowledge.

Robustness checks. The first robustness check includes the deviation of annual rainfall from its historical mean (for the period 1951-2007) as an additional regressor in the specifications evaluating the impact of smallholder area and smallholder production on per capita expenditure. For the sake of brevity we only present results for the specifications where our main results are obtained (see tables A8 and A9 in the Appendix). We use lagged values of rainfall because the SUSENAS survey is implemented at the beginning of the calendar year when the realization of the rainfall is unknown. Somewhat counterintuitively, the estimated coefficient of the rainfall variable is negative. However, it is only statistically significant in some specifications. The results for our main variable, palm oil, change little and importantly the magnitude of the smallholder area and smallholder production coefficients remain the same. However, the only notable difference is that the IV estimate of smallholder production for Sumatra and Kalimantan using historical values of production as exogenous source of variation is now only statistically significant at the 10.6% level (previously 10% level).[36]

In the second set of robustness checks we use the level form of per capita expenditure instead of logs.[37] Specifications for Indonesia as a whole where per capita expenditure is expressed in Indonesian rupiah are presented in table A10 in the Appendix and specifications for Sumatra and Kalimantan are presented in table 8 below. The results suggest that the findings discussed above are only conservative estimates on the impact of smallholder cultivated areas and smallholder palm oil production on household expenditure. For Indonesia as a whole, a thousand hectares increase in the district smallholder area decreases per capita expenditure by 932 rupiah (0.3 per cent of the average expenditure) and a thousand tonne increase in the district smallholder

[36] Because the sign of the estimated rainfall coefficient is not in line with our prior expectations the rainfall variable is excluded from our main specifications.
[37] We use logs in the main specifications because scaling the per capita expenditure may reduce the bias of possible outliers.

production decreases per capita expenditure by 411 rupiah (0.1 per cent of the average expenditure). For Sumatra and Kalimantan applying the estimated effects of the IV estimations the elasticities of the impact of smallholder area on per capita expenditure are -0.036 (historical values from PODES as an instrument) and -0.109 (historical forest area as an instrument). The corresponding elasticities for smallholder production are -0.032 and -0.105, respectively. More, without one exception, all estimates are statistically significant, at least marginally.

[Insert table 8 about here]

Health outcomes. The impact of palm oil expansion on health outcomes is measured by studying the probability of a household member reporting symptoms of asthma which is a binary variable. However, we are using OLS instead of logit or probit because OLS provides consistent estimates also in the IV framework. Asthma and difficulties in breathing could be associated with forest fires and toxic odours as well as waste coming being released by refineries, although there could also be other relevant health indicators. Using the data for Indonesia as a whole the results from both the OLS regression and IV regression suggest there is no statistically significant relationship between smallholder area and the prevalence of asthma (see table A11 in Appendix).[38] The same holds also with smallholder production (see table A12 in Appendix). The estimated effects are always negative, but fall short of statistical significance at conventional levels.

Similarly, results from restricting the sample to Sumatra and Kalimantan only suggest that neither smallholder production nor smallholder area has a statistically significant impact on the incidence of asthma (see table 9 below, for details tables A13 and A14 in Appendix).[39]

[Insert table 9 about here]

5.2 Total area in Kalimantan

The second set of results relates to the total plantation area (including both smallholders and large plantations) in Kalimantan only. A summary of the main results is presented in table 10 below. There are some limitations in the data with respect to Central Kalimantan, for which the

[38] It is notable that the individual data for all Indonesia is too large for estimation and therefore the data used in this study covers a 30% sample of individuals aged 10 and above, stratified by year and district.
[39] We also divided the sample into adults and children but could not find any statistically significant effect.

area and production data are unavailable, and also East Kalimantan where the production data is reported in fresh fruit bunches (FFB), not crude palm oil in tonnes. As a result the number of observation points, i.e. the number of districts in the total production specifications would be only 21 and therefore we are only estimating the effect of total palm oil area on household welfare.[40]

Per capita expenditure. OLS regressions on the impact of total plantation area give similar results to those for smallholders only. According to the OLS specifications the total district area of palm oil is negatively associated with household per capita expenditure but the estimates are not statistically significant at conventional levels (see table 10 below, column 1). The instruments do not have enough power to assess the causal relationship between the total area of oil palm and household expenditure. For example, using the historical values of oil palm area as exogenous source of variation the F-test of the first stage (2SLS regression) is only 1.57 (see the bottom part of column 1 in table 10 below).

Restricting the sample to rural households only does not change the overall finding that the total area of palm oil is only weakly associated with household expenditure, and the estimated coefficients do not gain statistical significance at conventional levels (see column 2 in table 10 below).

Health outcomes. The final set of results relates to the impact of total plantation area of palm oil in Kalimantan on the probability of individuals reporting symptoms of asthma. The OLS estimation suggests that there is a positive relationship between the total area of oil palm and the presence of breathing difficulties but the estimated coefficient is not statistically significant at the conventional levels. The IV estimation using the historical values for plantation areas as an exogenous source of variation in the prediction model confirms the positive relationship between total plantation area the incidence of asthma and now the estimated effect is statistically significant at the 5% level (see column 3 in table 10 below). The result is also robust to the inclusion of the rainfall variable (results not reported here). The estimated impact suggest that one thousand hectares increase in the total area of district oil palm plantations increases the probability of individual reporting breathing difficulties by 0.09 of a percentage point. The

[40] The cluster robust variance-covariance matrix is asymptotically consistent in the number of clusters. Ideally the number of clusters would therefore be relatively large and 21 seem to be too few clusters.

corresponding elasticity is 1.50.[41] The estimated effect for individuals living in rural areas is similar but now the effect is only marginally statistically significant at the 10% level. Also the F-test of the first stage is smaller 6.17, compared to 13.01 in the full sample (see column 4 in table 10 below). The average district-level total plantation area of palm oil in South, West and East Kalimantan increased around 11,100 hectares (57%) between 2005 and 2007. Employing the increase in total area listed above the results suggest that the prevalence of asthma increased by one percentage point in South, West and East Kalimantan as a result of the expansion in palm oil production.

[Insert table 10 about here]

6 Conclusion

In Indonesia, the area of oil palm plantations has increased by more than 2100 per cent since the 1980s. This expansion has been shown to have significant impacts on the environment, and particularly on forest degradation. There is also a general perception that palm oil production is an important driver of economic development in rural areas. However, there is little systematic empirical evidence of the welfare impacts of this expansion. There are a few small scale, location-specific studies looking at the effects of palm oil production on smallholder producers (see for example Feintrenie et al., 2010) and a descriptive study comparing province level outcomes (Kessler et al., 2007), but the aggregate welfare effects remain largely unknown. This study attempts to fill this gap.

In this paper we have studied the welfare impacts of district-level areas of oil palm plantations and levels of palm oil production on households located in these districts. We have discussed that palm oil production requires investments and knowledge, and that therefore the possible endogeneity problem must be addressed in any credible evaluation. We have identified two sources of potentially exogenous variation in palm oil production. First, we use historical values of palm oil area and production. Second, we use district-level forest area data in the period prior to our study to predict the oil palm plantations and production levels in the study period. Our

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[41] Elasticity is calculated: $\beta * \frac{\bar{x}}{\bar{Y}}$

primary focus is on smallholder production, both in Indonesia as a whole and separately in the two main production regions, Sumatra and Kalimantan. In addition, we study the welfare impact of total production in selected provinces in Kalimantan.

Two main findings emerge. First, the suggested positive spillover effects of palm oil production are not found in these data. The proponents of palm oil have argued that palm oil production could be the main driver of rural development in Indonesia. The findings of this study suggest that palm oil production has, if anything, a negative impact on household per capita expenditure both in Indonesia as a whole and in the main production regions, Sumatra and Kalimantan. Even if the weak negative effect is not present when the sample is restricted to rural households, we can rule out any positive impact. Moreover, an important robustness check where per capita expenditure is expressed in Indonesian rupiah instead of logs confirms the negative effect. In fact, in light of the results derived from these alternative specifications the main results presented in this paper are only conservative estimates. The findings are in contrast with the anecdotal evidence, which usually highlights a positive impact of palm oil production on farmers in the study villages (Feintrenie et al., 2010; Rist et al., 2010). Therefore the findings here are more in line with Kessler et al. (2007), who find mixed results on the socio-economic impacts of the palm oil production expansion. In addition, there is also evidence to suggest that some farmers might engage in unfair deals with the palm oil producing companies, in which case these farmers' debt may increase to unsustainable levels. It is also notable that previous studies have focused only on a few villages and therefore the results are difficult to generalize. However, it is important to note that the findings in this study do not suggest that individual farmers could not benefit from palm oil production. Rather, the results suggest that even if farmers had indeed benefitted from palm oil production, there is no evidence that these benefits would have been distributed to other households, at least in the short term.

Similarly to the findings regarding the impact of the smallholder production and area in Sumatra and Kalimantan, we have not found any evidence of a positive impact of total oil palm area or total palm oil production on household expenditure in selected provinces in Kalimantan. The OLS estimates point to a negative association, but the estimated coefficients fall short of statistical significance at conventional levels. However, due to the lack of power of our instruments in the IV, estimation we cannot assess the causal relationship between total area and household expenditure in Kalimantan.

Second important finding relates to health. Smallholder area and smallholder production do not have an impact on the incidence of asthma, neither for Indonesia as a whole or in Sumatra and Kalimantan only. However, we do find evidence that the total oil palm area in selected provinces in Kalimantan adversely affect health, as measured by the probability of a household member reporting symptoms of asthma. Both the area devoted to oil palm and palm oil production could have adverse health effects, the former due to forest clearing by burning the land and the latter due to odours and toxic waste being released by refineries.

The results confirm that palm oil production cannot be taken as a panacea to increase rural welfare, and therefore it would seem advisable to consider the cost and benefits in relation to the local conditions and environment before deciding any future expansions. Moreover, public subsidies for palm oil production should stop.

This study has not addressed the question of whether palm oil production has benefited individual farmers. However, the results suggest that smallholder production is, if anything, welfare reducing in the short term, and also that households not directly involved in the production are affected. Moreover, the lack of evidence of positive effect for the total production in selected provinces in Kalimantan is not consistent with the arguments put forward by the proponents of palm oil production. If palm oil production alters ecosystems and water management, for example, households need additional resources to cope with these changes.

These findings lay out various areas for future research. A natural step forward would be to replicate the study using firm-level data. Another interesting area for future research would be to study district level outcomes in order to benefit from panel analyses, and here potential outcomes would be poverty rates and regional GDP, among others. A further important extension would be to expand the study period to capture long-term effects. And finally, the question related of effect of palm oil expansion on migration is left for future research.

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Tables

Table 1. Village oil palm plantations (in hectares) and loss in rice fields.

	No loss in rice fields	Moderate loss in rice fields	Heavy loss in rice fields	All villages
Sumatra	58.9	64.4	345.6	63
Kalimantan	60.2	15.9	35.1	55
All Indonesia	26.5	13.2	151.8	25.2

Table 2. Village area of oil palm plantations (in hectares) and deforestation.

	No deforestation	Moderate deforestation	Heavy deforestation	All villages
Sumatra	55.7	54.8	344.6	63
Kalimantan	43.5	44.1	224.4	55
All Indonesia	21.1	28.4	178.1	25.2

Table 3. Descriptive statistics for district-level smallholder data in Sumatra and Kalimantan, years 2003-2006.

	Average (2003-2006)	2003	2006
Smallholder area (ha)	13,300 (24,200)	10,200 (18,600)	15,700 (27,800)
Smallholder production (tonnes)	26,500 (53,400)	19,600 (39,400)	35,500 (68,700)

Note: Standard deviations in parenthesis.

Table 4. Descriptive statistics for district-level palm oil plantation data for selected provinces in Kalimantan.

	Average (2005-2007)	2005	2007
Total area (ha)	25,200 (42,300)	19,600 (35,500)	30,700 (47,800)

Notes: Standard deviations in parenthesis. Area data include provinces of West, South and East Kalimantan. For West Kalimantan data are also available for 2004 that are included in the regression analysis.

Table 5. Descriptive statistics for per capita expenditure and asthma.

	Mean 2004-2007	Mean 2004	Mean 2007
	Indonesia		
PCE (in logs)	12.577 (0.583)	12.48 (0.534)	12.735 (0.649)
PCE (in Rupiah)	356,722.9 (402,832.8)	310,888 (289976.9)	433,926.3 (435074.1)
Asthma	0.018 (0.133)	0.015 (0.122)	0.028 (0.165)
	Sumatran and Kalimantan		
PCE (in logs)	12.567 (0.554)	12.476 (0.521)	12.714 (0.627)
PCE (in Rupiah)	342,887.8 (306427.9)	306,445 (256614)	415,511 (371,767.2)
Asthma	0.018 (0.132)	0.014 (0.116)	0.029 (0.168)

Note: Standard deviations in parenthesis.

Table 6. Prediction model for smallholder cultivation areas and production levels using the historical data for these measures as an exogenous source of variation.

	Area, All Indonesia	Area, Sumatra and Kalimantan	Production, All Indonesia	Production, Sumatra and Kalimantan
Oil palm area in 2002	0.0009*** (0.0003)	0.0009*** (0.0003)		
Palm oil production in 2002			0.0002*** (0.0001)	0.0002*** (0.0001)
Observations	1863	788	1863	788
F-test for instrument	10.47***	10.46***	7.46***	7.45***
District fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Province*year interactions	Yes	Yes	Yes	Yes

Robust standard errors in parenthesis

Cultivation area is expressed in hectares and palm oil production in tones. Oil palm area is interacted with predicted province area and palm oil production interacted with predicted province production.

Regression coefficients are multiplied by 1000.

* p<0.1, ** p<0.05, *** p<0.01

Table 7. Prediction model for smallholder cultivation areas and production levels using district forest area in 2000 as an exogenous source of variation.

	Oil palm area, Sumatra and Kalimantan	Palm oil production, Sumatra and Kalimantan
Forest area in 2000	0.0206*** (0.0061)	
Forest area in 2000		0.0109*** (0.0026)
Observations	773	773
F-test for instrument	11.54***	17.32***
District fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Province*year interactions	Yes	Yes
Forest area*year interactions	Yes	Yes

Robust standard errors in parenthesis

Oil palm area is expressed in hectares and palm oil production in tonnes. In the oil palm area model district forest area in 2000 is interacted with the predicted province area of oil palm, and in the production model district forest area is interacted with the predicted province palm oil production.

Regression coefficients are multiplied by 1000.

* p<0.1, ** p<0.05, *** p<0.01

Table 8. Robustness check, per capita expenditure in rupiah. The impact of smallholder area and smallholder production on per capita expenditure in Sumatra and Kalimantan. OLS and IV estimates.

Dependent variable	PCE (in Rupiah)		
	OLS	IV; PODES	IV; FOREST
1. Regression			
Smallholder area	-0.4877172*	-0.9387319*	-2.8128613**
	(0.2746122)	(0.4897851)	(1.2511221)
Observations	323114	323114	317720
F-test 1st stage		46.37***	9.59***
2. Regression			
Smallholder production	-0.1872073	-0.4141861**	-1.3540752*
	(0.1214678)	(0.2037791)	(0.6990902)
Observations	323114	312114	317720
F-test 1st stage		44.94***	7.00***

Robust standard errors in parenthesis
Household controls include household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.
* p<0.1, ** p<0.05, *** p<0.01

Table 9. The impact of smallholder area and smallholder production on log household per capita expenditure and asthma in Sumatra and Kalimantan; summary of the main results.

Dependent variable	LOG PCE		ASTHMA	
	All households	Rural households	All households	Rural households
		OLS		
Smallholder area	-0.0010	-0.0009	-0.000043	-0.000090
	(0.0009)	(0.0009)	(0.000044)	(0.000064)
Smallholder production	-0.0004	-0.0002	-0.000010	-0.000025
	(0.0004)	(0.0003)	(0.000019)	(0.000028)
		IV		
Smallholder area	-0.0016	-0.0015	-0.000112	-0.000264
	(0.0011)	(0.0010)	(0.000121)	(0.000208)
Smallholder production	-0.0009*	-0.0006	-0.000050	0.000101
	(0.0005)	(0.0004)	(0.000060)	(0.000096)

In the IV estimation historical values of smallholder production/smallholder area from PODES agricultural survey are used. Regression coefficients are multiplied by 1000 and therefore the estimated effect is for a 1000 ha increase in the area specifications and a 1000 tonnes increase in the production specifications.

Table 10. The impact of total area on log household per capita expenditure and asthma in South, West and East Kalimantan, summary of the main results.

Dependent variable	LOG PCE		ASTHMA	
	All households	Rural households	All households	Rural households
		OLS		
Total plantation area	0.0081	-0.0048	0.0002	0.0002
	(0.0060)	(0.0064)	(0.0001)	(0.0001)
Observations	32,726	21,995	181,070	119,475
		IV		
Total plantation area	-0.0015	0.0053	0.0009**	0.0009*
	(0.0215)	(0.0204)	(0.0004)	(000006)
F-test 1st stage	1.57	0.8	13,13**	6.17**
Observations	32,726	21,995	181,070	119,475

Robust standard errors in parenthesis

In column (1) additional household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head and in column (2) additional household controls include household size, the gender, age, education, industry category and work type of the household head. In column (3) additional household controls include rural/urban and gender of the head and dummy variables indicating whether household has own toilet, uses tap water and owns the dwelling and additional individual controls include age, education and industry category. In column (4) additional household controls include gender of the head and dummy variables indicating whether household has own toilet, uses tap water and owns the dwelling and additional individual controls include age, education and industry category. All regressions also include district and year fixed effects and province*year interaction term. In the IV estimation historical values of smallholder production/smallholder area from PODES agricultural survey are used. Regression coefficients are multiplied by 1000 and therefore the estimated effect is for a 1000 ha increase. * p<0.1, ** p<0.05, *** p<0.01

Table A1. Prediction models for total palm oil plantation area (including both smallholders and large plantations) in selected provinces in Kalimantan.

	Area with historical values from Podes	Area with district forest area in 2000
Oil palm area in 2002	0.0027*** (0.0007)	
Palm oil production in 2002		
Forest area in 2000		0.0037 (0.0156)
Forest area in 2000		
Observations	145	140
F test for instrument	16.46***	0.05
District fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Province*year interactions	Yes	Yes
Forest area*year interactions	No	Yes

Robust standard errors in parenthesis
Instruments are interacted with predicted province area of palm oil.
Regression coefficients are multiplied by 1000.
* p<0.1, ** p<0.05, *** p<0.01

Table A2. The impact of smallholder area on LOG PCE, Indonesia as a whole. OLS and IV estimates.

Dependent variable:	LOG PCE			
	OLS, All	IV; All	OLS; Only rural	IV; Only rural
Smallholder area	-0.0000012	-0.0000016	-0.0000011	-0.0000015
	(0.0000009)	(0.0000011)	(0.0000009)	(0.0000010)
Observations	839918	839918	518724	518724
F-test 1st stage		46.41***		51.85***

Robust standard errors in parenthesis
In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.* p<0.1, ** p<0.05, *** p<0.01

Table A3. The impact of smallholder production on LOG PCE, Indonesia as a whole. OLS and IV estimates.

Dependent variable	LOG PCE			
	OLS, All	IV; All	OLS; Only rural	IV; Only rural
Smallholder production	-0.0000005 (0.0000004)	-0.0000009* (0.0000005)	-0.0000003 (0.0000003)	-0.0000006 (0.0000004)
Observations	839918	839918	518724	518724
F-test 1st stage		44.79***		49.97***

Robust standard errors in parenthesis

In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.* p<0.1, ** p<0.05, *** p<0.01

Table A4. The impact of smallholder area on log PCE in Sumatra and Kalimantan. OLS and IV estimates.

Dependent variable	LOG PCE			
	OLS, wo fixed effects	OLS	IV; PODES	IV; FOREST
Smallholder area	-0.0000000 (0.0000004)	-0.0000010 (0.0000009)	-0.0000016 (0.0000011)	-0.0000045* (0.0000025)
District fixed effects	No	Yes	Yes	Yes
State*year fixed effects	No	Yes	Yes	Yes
Observations	323114	323114	323114	317720
F -test 1st stage			46.34***	9.59***

Robust standard errors in parenthesis
In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include year fixed effects.* p<0.1, ** p<0.05, *** p<0.01

Table A5. The impact of smallholder area on LOG PCE in Sumatra and Kalimantan. OLS and IV estimates, only rural households.

Dependent variable	LOG PCE		
	OLS; Only Rural	IV; PODES; Only rural	IV; FOREST ;Only rural
Smallholder area	-0.0000009	-0.0000015	-0.0000119*
	(0.0000009)	(0.0000010)	(0.0000065)
Observations	214312	214312	212216
F-test 1st stage		51.72***	4.18**

Robust standard errors in parenthesis

In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.

* p<0.1, ** p<0.05, *** p<0.01

Table A6. The impact of smallholder production on LOG PCE in Sumatra and Kalimantan, OLS and IV estimates, all households.

Dependent variable	LOG PCE			
	OLS, wo fixed effects	OLS	IV; PODES	IV; FOREST
Smallholder production	-0.0000001 (0.0000002)	-0.0000004 (0.0000004)	-0.0000009* (0.0000005)	-0.0000024* (0.0000014)
District fixed effects	No	Yes	Yes	Yes
State*year fixed effects	No	Yes	Yes	Yes
Observations	323114	323114	323114	317720
F -test 1st stage			44.93***	7.0***

Robust standard errors in parenthesis

In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include year fixed effects.* p<0.1, ** p<0.05, *** p<0.01

Table A7. The impact of smallholder production on LOG PCE in Sumatra and Kalimantan, OLS and IV estimates, only rural households.

Dependent variable	LOG PCE		
	OLS; Only Rural	IV; PODES, Only Rural	IV; Forest, Only Rural
Smallholder production	-0.0000002	-0.0000006	-0.0000032
	(0.0000003)	(0.0000004)	(0.0000024)
Observations	214312	214312	212216
F-test 1st stage		50.18***	3.54*

Robust standard errors in parenthesis
Household controls include household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.
* p<0.1, ** p<0.05, *** p<0.01

Table A8. Robustness check with rainfall. The impact of smallholder production on log household per capita expenditure, OLS and IV estimate, Indonesia as a whole.

Dependent variable	LOG PCE	
	OLS	IV, PODES
Smallholder production	-0.0000005	-0.0000009*
	(0.0000004)	(0.0000005)
Rainfall	-0.0085450**	-0.0085066**
	(0.0038878)	(0.0038898)
Observations	837170	837170
F-test 1st stage		44.67***

Robust standard errors in parenthesis
Lagged values of deviation of annual rainfall from its historical mean included as an additional control.
In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.* p<0.1, ** p<0.05, *** p<0.01

Table A9. Robustness check with rainfall. The impact of smallholder area and smallholder production on log PCE, IV estimates, only Sumatra and Kalimantan.

Dependent variable	LOG PCE			
	AREA, IV; PODES	AREA, IV; Forest	PRODUCTION, IV; PODES	PRODUCTION, IV; Forest
Smallholder area	-0.0000016	-0.0000044*		
	(0.0000012)	(0.0000023)		
Smallholder production			-0.0000008	-0.0000023*
			(0.0000005)	(0.0000013)
Rainfall	-0.0124548	-0.0143570*	-0.0113173	-0.0113943
	(0.0080980)	(0.0086547)	(0.0082314)	(0.0089083)
Observations	323114	317720	323114	317720
F-test 1st stage	50.58***	9.65***	44.93***	7.04***

Robust standard errors in parenthesis

Lagged values of deviation of annual rainfall from its historical mean included as an additional control. In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.

* p<0.1, ** p<0.05, *** p<0.01

Table A10. Robustness check, per capita expenditure in rupiah. The impact of smallholder area and production on per capita expenditure, Indonesia as a whole.

Dependent variable	PCE (in Rupiah)	
	OLS	IV, PODES
Regression 1.		
Smallholder area	-0.589**	-0.932*
	(0.276)	(0.485)
Observations	839918	839918
F-test 1st stage		46.41***
Regression 2.		
Smallholder production	-0.235*	-0.411**
	(0.124)	(0.201)
Observations	839918	839918
F-test 1st stage		44.79***

Robust standard errors in parenthesis
In the IV-regressions historical values from PODES2003 as an instrument are used. Household controls include urban/rural, household size, the gender, age, education, industry category and work type of the household head. All regressions also include district and year fixed effects and province*year interaction term.* p<0.1, ** p<0.05, *** p<0.01

Table A11. The impact of smallholder area on asthma. OLS and IV estimates, Indonesia as a whole.

Dependent variable	Asthma			
	OLS, All	IV; PODES, All	OLS; Only Rural	IV; PODES, Only Rural
Smallholder area	-0.000000077	-0.000000098	-0.000000121	-0.000000217
	(0.000000057)	(0.000000152)	(0.000000080)	(0.000000258)
Observations	825670	825670	503484	503484
F-test 1st stage		49.01***		53.80***

Robust standard errors in parenthesis
Dependent variable is a dummy variable indicating whether individual suffered from breathing problems. In the IV regressions historical values from PODES as an instrument are used. Household controls include rural/urban and gender of the head and dummy variables indicating whether household has own toilet, uses tap water and owns the dwelling. Individual controls include age, education and industry category. All regressions also include district and year fixed effects and province*year interaction term.
* p<0.1, ** p<0.05, *** p<0.01

Table A12. The impact of smallholder production on asthma, OLS and IV estimates, Indonesia as a whole.

Dependent variable	Asthma			
	OLS, All	IV; PODES, All	OLS; Only Rural	IV; PODES, Only Rural
Smallholder production	-0.000000009 (0.000000023)	-0.000000027 (0.000000067)	-0.000000017 (0.000000029)	-0.000000062 (0.000000106)
Household controls	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes
Observations	825670	825670	503484	503484
F -test 1st stage		45.65***		52.17***

Robust standard errors in parenthesis
Dependent variable is a dummy variable indicating whether individual suffered from breathing problems. In the IV regressions historical values from PODES as an instrument are used. Household controls include rural/urban and gender of the head and dummy variables indicating whether household has own toilet, uses tap water and owns the dwelling. Individual controls include age, education and industry category. All regressions also include district and year fixed effects and province*year interaction term.
* p<0.1, ** p<0.05, *** p<0.01

Table A13. The impact of smallholder area on asthma, OLS and IV estimates. Only Sumatra and Kalimantan.

Dependent variable	Asthma			
	OLS, All	IV; PODES, All	OLS; Only Rural	IV; PODES, Only Rural
Smallholder area	-0.000000043	-0.000000112	-0.000000090	-0.000000264
	(0.000000044)	(0.000000121)	(0.000000064)	(0.000000208)
Observations	1073420	1073420	700250	700250
F-test 1st stage		48.85***		53.93***

Robust standard errors in parenthesis
Dependent variable is a dummy variable indicating whether individual suffered from breathing problems. In the IV regressions historical values from PODES as an instrument are used. Household controls include rural/urban and gender of the head and dummy variables indicating whether household has own toilet, uses tap water and owns the dwelling. Individual controls include age, education and industry category. All regressions also include district and year fixed effects and province*year interaction term.
* p<0.1, ** p<0.05, *** p<0.01

Table A14. The impact of smallholder production on asthma, OLS and IV estimates. Only Sumatra and Kalimantan.

Dependent variable	Asthma			
	OLS, All	IV; PODES, All	OLS; Only Rural	IV; PODES, Only Rural
Smallholder production	-0.000000010	-0.000000050	-0.000000025	-0.000000101
	(0.000000019)	(0.000000060)	(0.000000028)	(0.000000096)
Observations	1073420	1073420	700250	700250
F-test 1st stage		45.89***		52.23***

Robust standard errors in parenthesis
Dependent variable is a dummy variable indicating whether individual suffered from breathing problems. In the IV regressions historical values from PODES as an instrument are used. Household controls include rural/urban and gender of the head and dummy variables indicating whether household has own toilet, uses tap water and owns the dwelling. Individual controls include age, education and industry category. All regressions also include district and year fixed effects and province*year interaction term.
* p<0.1, ** p<0.05, *** p<0.01