Exploring the Trade-offs between Land Use and Income Changes due to Palm Oil Industry Expansion in Indonesia

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Abstract

Indonesia's palm oil industry is an important economic driver, but it is also considered to be a major cause of deforestation. This paper reviews the impact of the palm oil industry expansion on Indonesia's economy using a partial equilibrium model. We consider three potential causes: growth in foreign demand; land policy; and productivity growth. Land policy produces a large impact in forest losses and positive impact on labour income changes. Growth in foreign demand gives a less severe impact on forest cover and a higher impact on labour incomes. Finally, productivity growth causes smaller impacts on forest cover but also little impact on labour incomes.

Abstrak

Industri kelapa sawit Indonesia merupakan salah satu penggerak perekonomian; namun, di sisi lain dipercaya sebagai sumber kerusakan hutan. Tulisan ini mengulas dampak dari pertumbuhan industri kelapa sawit menggunakan model keseimbangan parsial. Kami mengulas beberapa kemungkinan penyebab pertumbuhan di sektor ini, antara lain: pertumbuhan permintaan; kebijakan pertanahan; dan peningkatan produktivitas. Kebijakan pertanahan memberikan efek yang besar pada kerusakan hutan tetapi pada saat bersamaan memberikan peningkatan pendapatan yang cukup besar. Pertumbuhan permintaan memberikan efek lebih kecil terhadap kerusakan hutan dan mampu menghasilkan pertumbuhan pendapatan yang besar. Sedangkan, peningkatan produktivitas menimbulkan kerusakan hutan terkecil tetapi hanya memberikan pengaruh yang kecil pada peningkatan pendapatan.

Key words: the palm oil industry, partial equilibrium model, forest loss, income changes.

JEL classification: O13, O53, Q12, Q15.

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1. Introduction

Palm oil is believed to be the fastest growing perennial crop in the world (Koh and Wilcove, 2008). The total harvested land has increased by 4.6% annually from 6.1 million ha in 1990 to 18.1 million ha in 2013 worldwide (FAOSTAT, 2015b) and global production has grown by 7.2% annually from 11 million metric tonnes to 59.6 million metric tonnes during the same periods (USDA-FAS, 2015b). Data from USDA-FAS (2015b) shows that in Indonesia, the growth rates are even bigger, the harvested area of oil palm has grown by 10.3% and production and exports have grown by 10.7% and 11.9%, respectively, between 1990 and 2013.

Around 50% of global palm oil is produced in Indonesia. Indonesia's palm oil has gained high growth since early 1990's and overtook Malaysia in 2005 as the world's largest palm oil producer. Both Indonesia and Malaysia's combined market is 85% of the world's total production and 90% of the world's total export in 2013/2014 (USDA-FAS, 2015b).

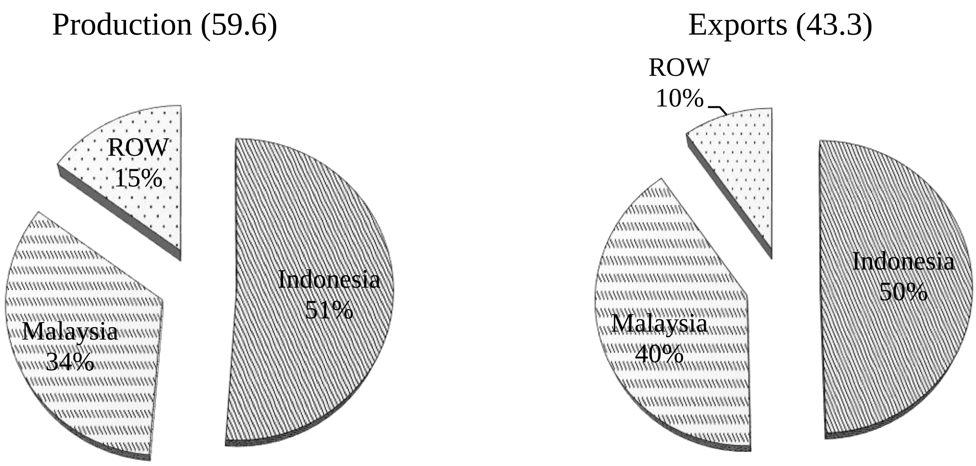
While palm oil is not the most important crop product in Indonesia, its share within crop agriculture increased significantly from 2.4% in 2000 to 8.4% in 2008. Indonesia's crop agriculture is dominated by rice crop with the share of 24.41% in 2008, this number decreased from 32.4% in 2000. In the group of plantation crops, in 2008, palm oil is the most important crop with the share of 8.4%, while rubber comes second with the share of 4.6%. It is also important to notice that the shares of all other plantation crops are diminishing over time, except for palm oil. Table 1 shows the shares of several types of crops in Indonesia based on Indonesia's input output table in 2000, 2005 and 2008.

Palm oil expansion is causing forest destruction (Koh and Wilcove, 2008, Laurance, 2007). The improvement in oil palm plantation's yield is relatively very low, more notably in Indonesia (Carter et al., 2007, Dros, 2003), so that the easiest way to expand the production is by increasing land expansion.

Indonesian and Malaysian governments are already under international pressure regarding oil palm plantation expansion. However, palm oil is very important for both countries economically, more notably for rural areas (Koh and Wilcove, 2007). For Malaysia, palm oil accounted for 4 percent of its total GDP in 2013, increased from 3 percent in 2005 (DOSM, 2014). For Indonesia, the share of palm oil to total GDP is smaller than Malaysia at only 0.4

percent in 2005, but increased to 0.8 percent in 2008 (BPS, 2006, BPS, 2009). However, palm oil contributes to around almost 11 percent of Indonesia's total merchandise exports in 2014, increased from only 2 percent in 2000 (WITS, 2015). While for Malaysia, it accounted for 2.6 percent in 2000 and 5.5 percent in 2014 of Malaysia's total merchandise exports (WITS, 2015).

Figure 1. Market shares of global palm oil (million metric tonnes), 2013/2014



Source : USDA-FAS (2015b)

Table 1. Shares of crop outputs in Indonesia (percentage)

Type of crops	2000	2005	2008
Food crops	75.03	74.85	74.25
Rice	32.38	25.57	24.41
Maize	6.21	8.00	11.01
Roots and yams	9.40	7.65	4.90
Vegetables and fruits	22.94	29.79	31.05
Other food crops	4.09	3.84	2.58
Plantation crops	24.97	25.15	25.75
Rubber	5.80	6.75	4.58
Sugar cane	2.67	1.95	1.39
Coconut	3.87	3.16	2.68
Palm oil	2.42	5.11	8.35
Tobacco	0.35	0.43	0.36
Coffee	0.90	2.48	1.31
Tea	0.35	0.26	0.17
Clove	0.90	0.79	0.47
Other plantation crops	7.70	4.23	6.05

Source:BPS (2006), BPS (2009).

Table 2. Shares of Indonesia's palm oil and palm kernel oil exports (percentage)

year	Shares of Palm Oil (PO) and Palm Kernel Oil (PKO) exports[a] to		
	Total merchandise[b]	Total agriculture[c]	Crop agriculture[d]
1990	1.06	5.96	9.21
1995	2.23	11.40	16.97
2000	2.26	17.08	27.37
2005	5.36	30.34	39.91
2010	10.16	42.26	49.36

Source: WITS (2015)
[a] Based on SITC Revision 3, 4 digit codes: PO (4222) and PKO (4224)
[b] 1 digit codes: 0,1,2,3,4,5,6,7,8,9.
[c] 1 digit codes: 0,1,2,4 (for code 2, excluding 27 and 28).
[d] 2 digit codes: 04,05,06,07,08,09,12,22,23,26,42,43.

This paper reviews the impact of oil palm plantation expansion on Indonesia's economy. We develop a partial equilibrium model to analyse the impacts of the oil palm plantation expansion on labour and income changes. We will also consider the impact of this development on forest cover. We consider three types of potential causes for the expansion of palm oil, namely: growth in foreign demand; land use policies; and productivity growth.

There are several studies on productivity growth in palm oil sector in Indonesia and Malaysia, for examples Dros (2003), Wicke et al. (2011), and Villoria et al. (2013). They focus on the land use changes only and do not consider income changes. Other group of studies, like Zen et al. (2005), Feintrenie et al. (2010a), and Rist et al. (2010) focus on the impacts of palm oil expansion on the livelihood of Indonesian farmers. But these studies are based on interviews and very specific to certain regions.

More comprehensive research can be found in Sandker et al. (2007) who simulate the impact of palm oil plantation expansion on forest cover, immigration, and income changes. However, their research is specifically focus on Malinau district in North Kalimantan (before: East Kalimantan). Other research by Lee et al. (2014) also assessing the trade-offs between environment and socio-economic outcomes of oil palm expansion in Sumatra, Indonesia. Their simulations are based on whether smallholders or industrial estates are more dominance in the expansion. Both simulations are done using models specifically designed for land cover change.

We try to assess the impacts of the palm oil industry expansion on both land use and economic aspects in Indonesia.

We find that the impact of palm oil growth on incomes and deforestation, depends on the cause. Land policy scenarios produce a relatively large impact in forest losses and positive impact on labour income changes. But if the prime cause is growth in foreign demand we find that there is a less severe impact on forest cover loss and a higher impact on labour incomes. Finally if productivity growth is included then there is less impact on forest cover but also little impact on wage incomes of labour.

The remainder of this paper is organised as follows: the following section reviews the issues on income versus environment. Section 3 examines the driving factors behind the boom in palm oil demand, whether food or biofuel consumptions. In section 4, we present the oil palm plantation structures in Indonesia, followed by section 5 that discusses the modelling frameworks. In section 6, we will have data and calibrations. The experiment design will be explained in section 7 and the results will be discussed in section 8. Finally, we will conclude the paper in section 9.

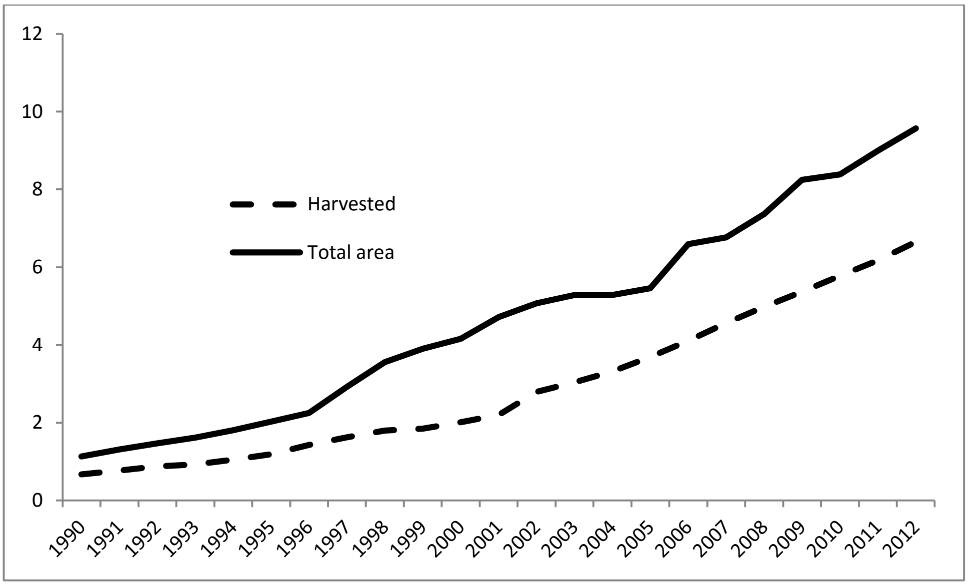
2. Income versus Environment

The palm oil industry is an important economic sub-sector in Indonesia. It is an important source of Indonesia's export revenue. It is also an important economic driver in rural areas (Koh and Wilcove, 2007, Zen et al., 2005, Feintrenie et al., 2010a). According to Härdter et al. (1997), the average income of oil palm smallholder farmers was seven times larger than the average income of subsistence farmers. Studies by Rist et al. (2010) and Feintrenie et al. (2010a) find that palm oil has increased the livelihood of smallholding farmers through higher returns to land and labour in Indonesia. The palm oil industry also creates jobs for millions Indonesians both in plantation and its downstream industries (Bahroeny, 2009, Media, 2013) and it is also linked to poverty alleviation (Susila, 2004).

Despite its economic importance, oil palm plantation is considered as a major cause of deforestation (FWI/GFW, 2002, Wilcove and Koh, 2010). Data from FAO shows that between 1990 and 2012, the matured area of oil palm plantation has expanded from 6.1 to 17.5 million ha worldwide (FAOSTAT, 2015b). The largest area of oil palm plantation is in Indonesia (6.7 million ha in 2012) and the second largest area is Malaysia (4.4 million ha) (FAOSTAT, 2015b). During that period, Indonesia has the highest growth in oil palm matured area expansion, increased from 0.7 million ha in 1990 to 6.7 million ha in 2012.

This expansion has led to an extensive forest loss. Koh and Wilcove (2008) show that during 1990-2005, at least 56% to the maximum 100% of oil palm plantation expansion in Indonesia takes place in forest area. While in Malaysia, the number is smaller, only 55% to 59% of oil palm expansion comes from forest conversion, and the other 41% to 45% comes from the conversion of other croplands (Koh and Wilcove, 2008). During that period, Indonesia has lost 25.5 million ha of forest, a lot higher than Indonesia's total oil palm area (26% of total forest loss), while total forest cover loss in Malaysia is only 2.1 million ha (FAOSTAT, 2015a). Hence, in Indonesia, it is more likely that the largest proportion of oil palm plantation expansion has been the result of forest conversion.

Figure 2. Oil palm plantation area in Indonesia (million ha)



Source: FAOSTAT (2015b) and MoA (2015)

From biodiversity point of view, the deforestation rates in Southeast Asia, especially in Indonesia and Malaysia, are alarming. The deforestation rates in Southeast Asia, are considered as the highest compared to other regions, with the annual rate of -0.8% to -0.9% or almost twice as in Latin America (-0.4% to -0.5%) (Mayaux et al., 2005). These two countries, particularly Indonesia, are home to almost 80% of tropical forests in this region (Fitzherbert et al., 2008, Koh and Wilcove, 2007). Indonesia is located in two out of 25 global biodiversity hotspots (Sundaland and Wallacea), places with highest number of biological diversity and endemic species but at the same time face high risk of extinction (Myers et al., 2000). For example Sundaland (Sumatra, Peninsular Malaysia, Borneo/Kalimantan, and Java) is among the hottest "hotspots", which accounts for 5% and

2.6% of total global plants and vertebrates that could not be found anywhere else (Myers et al., 2000). Unsurprisingly, Sumatra, Borneo/Kalimantan and Peninsular Malaysia are also known as areas with the highest concentration of oil palm plantations.

Beside biodiversity issue; forest conversion to plantation is also related to greenhouse gas (GHG) emissions. The emissions, particularly CO_2, from the palm oil industry come from land use change (LUC), forest and peat fires and peat oxidation when oil palm plantations are established on peat land (Agus et al., 2013). Indonesia is among the top countries in term of carbon emissions, and most of the emissions in Indonesia come from LUC (Harris et al., 2012, MoE, 2010). Oil palm plantation is a monoculture plantation; therefore, it stores less carbon than forest, even compared to other plantations like timber and rubber plantations (Agus et al., 2013).

Since less land is able to be converted to oil palm plantation, currently, oil palm plantation has been expanded on peat land in Indonesia and Malaysia (Germer and Sauerborn, 2008, Miettinen et al., 2012). Peat lands are the most carbon-rich type of land that has been accumulated over thousands of years, releasing carbon from peat lands is done through drainage and burn. According to DNPI (2010) the emissions from peat land account for 38% of Indonesia total emissions in 2005.

Perhaps, the most catastrophic forest fire event in Indonesia happened during the El Nino in 1997. Page et al. (2002) estimate that approximately 0.81-2.57 Gt of carbon were released during 1997 forest fire in Indonesia. These numbers are equivalent to 13-40% of global fossil fuels annual emissions (Page et al., 2002). And arguably, it is also highly related to oil palm plantation expansions (Casson, 2000, Glastra et al., 2002). It is a common practice in Indonesia to use fire to clear the land for oil palm plantation as it is easier and less expensive.

To reduce the pressure on the environment, Germer and Sauerborn (2008) suggest to promote the new establishment of oil palm plantations on former grasslands, as it will fix carbon stock. Moreover, through the better practice by improving yield, the pressure on the environment could also be minimised. Studies by Dros (2003) and Wicke et al. (2011) find that under better practice, the land expansion for oil palm plantation can be cut by almost a half to get similar output growth than if there is no improvement on yield.

3. Demand for Food versus Biodiesel

The production of palm oil is predicted to expand as demand for vegetable oils is continuing to increase. According to Corley (2009), the medium estimate of global palm oil demand in 2050 is projected between 120 and 156 million metric tonnes. This numbers are twice to almost three times larger than palm oil production in 2013/2014 which is 59.6 million metric tonnes (USDA-FAS, 2015b). There are at least two driving factors for the increase in demand for vegetable oil in general; *first* is the increasing in per capita consumption as a result of the increasing in per capita income in many developing countries. Particularly, since the average per capita daily fat intake in many developing countries is still below the ideal rate and still far below the "western" level (Corley, 2009, Thoenes, 2006). Palm oil is mainly used as food, although, there is a decreasing trend on the proportion of palm oil served as food. According to USDA-FAS (2015a), in 2013/2014, the share of palm oil used for food consumption was 69%, decreased from 79% in in 2002/2003.

The *Second* reason is the increasing demand for biofuels. The increasing price of fossil oil in the last decade and the interest to reduce GHG emissions have led many countries to diversify their conventional energy sources to the renewable energy sources (Koh and Ghazoul, 2008, Zhou and Thomson, 2009). Nowadays, most of biofuels come from ethanol (bio-ethanol), while, biofuels derived from vegetable oils (biodiesels) only come second (Thoenes, 2006). Global production of bio-ethanol is dominated by Brazil and the USA and the production of biodiesel is dominated by Europe (Zhou and Thomson, 2009, Koh and Ghazoul, 2008). Within the group of vegetable oils, the use of palm oil as a feedstock for biodiesel in Europe is still limited compared to other vegetable oils domestically produced in European countries like rapeseed oil.

However, over time, the application of palm oil for biodiesel feedstock has increased very substantially in Europe. According to Gerasimchuk and Koh (2013), palm oil's share for biodiesel feedstock has increased from 8% to 20% between 2006 and 2012, on the other hand, the share of rapeseed oil has decreased from 66% to 57%. This increase in palm oil based biodiesel is equivalent an increase from 0.4 to 1.9 million metric tonnes (Gerasimchuk and Koh, 2013). While, the use of palm oil for food in Europe has only slightly increased from 3.7 million metric tonnes in 2006 to 3.9 million metric tonnes in 2012 (Gerasimchuk and Koh, 2013).

Biofuels, especially biodiesel, could potentially be produced in a large quantity in Asian countries, especially in Indonesia (Zhou and Thomson, 2009, Wirawan and Tambunan, 2006). Indonesian government has committed to increase the use of biofuel, mostly biodiesel derived from palm oil due to several reasons like the high dependency on petroleum import, the increase in petroleum price, the availability of raw material and the concerns over air pollution in many major cities in Indonesia (Wirawan and Tambunan, 2006). Indonesian Presidential Decree no.5/2006 has targeted the mandatory use of renewable energy to 17% in which 5% coming from biofuels by 2016-2025 (Legowo et al., 2007). These figures equivalent to 22.26 million kL of biofuels where 10.22 million kL coming from biodiesel (mostly palm oil based) and 6.28 coming from bio-ethanol (Legowo et al., 2007).

Despite some negative campaigns by many environmentalists over palm oil based biodiesel, study by Pehnelt and Vietze (2009) states that in the context of GHG savings, biodiesel derived from palm oil is more efficient than other vegetable oil based biodiesels including rapeseed oil. This efficiency is measured from the relative yields, less energy and less fertilizer needed compared to other oilseed plants, and more importantly, oil palm plantation supports more species than other oilseed agricultures (Pehnelt and Vietze, 2009).

However, even without the development of biofuel market, demand for palm oil will still grow fast since the demand growth of edible oil and other purposes like cosmetics and processed food is still growing strongly (Corley, 2009, Sayer et al., 2012).

4. Structure of Indonesia's Oil Palm Estates

In Indonesia, oil palms are planted by three different groups: government estates, private estates, and smallholders. Recently, private estates have the biggest share, following by smallholding estates. It is important to note that the shares of smallholding estates have been increasing very rapidly, especially after 2000, both in terms of area and production. While, public estates have lost their importance through time. Table 3 shows the shares of each type of oil palm estates.

Table 3. Area and production of oil palm in Indonesia (1970-2010)

Items	1970	1980	1990	2000	2010	2014*
Planted area ('000 ha)						
Government estates	86.6(65)	199.5(68)	372.3(33)	588.1 (14)	658.5 (8)	840.0 (8)
Private estates	46.7(35)	88.9(30)	463.1(41)	2,403.2(58)	4,503.1(53)	4,467.2 (50)
Smallholdings	-	6.2 (2)	291.3(26)	1,166.8(28)	3,387.3(40)	4,453.1 (42)
Total	133.3	294.6	1,126.7	4,158.1	8,548.8	10,850.3
Production CPO('000 ton)						
Government estates	147.0(68)	498.9(69)	1,247.2(52)	1,461.0(21)	1,921.7(9)	2,501.9(9)
Private estates	69.8(32)	221.5(31)	788.5(33)	3,633.9(52)	12,116.5(54)	15,732.8(56)
Smallholdings	-	0.8 (0)	377.0(16)	1,905.7(27)	8,458.7 (38)	9,786.6(35)

Total	216.8	721.2	2,412.6	7,000.5	22,496.9	28,021.3

Note: numbers in the parentheses indicate percentage shares. * indicates preliminary figures.
Source: Barlow, Zen et al. (2003), BPS (2012), BPS (2014)

Recently, approximately 40% of oil palm area is occupied by smallholders. However, this development cannot be separated from government initiatives and the role of big estates, both government owned and private estates. Over many years, the development of smallholding oil palm plantation has been associated with the partnership between smallholders and big estates through nucleus and plasma model (NES), where big estates act as the nucleus and smallholders act as the plasma. This model has been introduced to Indonesia in the late 1970's. Over time, this model has been transformed into several types of schemes. But, the general practice is that the government issues land permit to the estate companies, under the condition that the companies have to incorporate smallholders by giving certain shares of the land to smallholders when the plants are ready to be harvested. In return, the smallholders have to sell their oil palm fruits only to company's mills and repay the capital spent by the estates as credit repayment. This model, has been unexpectedly very successful despite some technical difficulties during the settlement periods (Barlow et al., 2003).

The individual smallholders, on the other hand, do not tie themselves to such schemes and act like conventional farmers. While, there is no exact number on how the proportion splits between the scheme smallholders and the individual smallholders, Lee et al. (2014) suggest that they share an equal proportion. Suharto (2009) cited by Bissonnette and De Koninck (2015) estimates that independent smallholders cultivate approximately 1.8 million ha.

The smallholders who engage in the partnership schemes, somehow benefited more compared the individual smallholders, as the former can secure credit for planting, access to technical support and high-yielding palm tree seeds, and most importantly, access to estate's mills (Barlow et al., 2003, Zen et al., 2005, Sayer et al., 2012). Palm fruits have to be process within 24 hours after harvested, so that the access to mills is very important. The lack of assistance for the individual smallholders results in lower yield, lower quality, and therefore lower net return. Study by Zen et al. (2005) indicates that the net return of low-yielding smallholdings is almost 50 percent less that their plasma smallholding counterparts. However, recently, there is an improvement in the independent smallholdings through better knowledge and skills, better access to credits and the establishment of independent mills (Zen et al., 2005, Sayer et al., 2012, McCarthy et al., 2012).

5. Modelling Oil Palm Plantation

We develop a partial equilibrium model to analyse the impacts of oil palm plantation expansion on income, output, price, employment rates and land use. In this model, we only consider crop agriculture, while other sectors in the economy are held constant.

We consider a model with three goods: palm oil; other plantation goods; and, non-traded agricultural goods.

Non-traded agriculture is self-produced and self-consumed by farming household. We specify production factors into two: labour and land. Furthermore, household can choose to work for plantation firms and receive wage or work on its own field. We also consider two firms, oil palm plantation firm and other plantation firm. The objectives of each agent can be explained as follows:

- *Households*: we consider a representative farming household. The household owns labour and consumes imported good (good from non-agriculture sector) and non-traded agricultural good, which is self-produced by the household.
- *Plantation Firms*: we assume two representative firms: an oil palm plantation firm, and other plantation firm. Each firm minimises the cost for producing output by choosing labour and land, for given factor input prices.
- *World's consumers*: we assume that all plantation outputs are exportable. Therefore, the world market will consume all outputs produced by both plantation firms.

To simplify, we make several assumptions; first, labours are immobile to other non-agriculture sectors, but mobile within crop agriculture sectors. Second, land is mobile within plantation sectors only, but immobile to non-traded agriculture and non-agriculture sectors. Therefore, substituting land from other plantation crop to oil palm, *vice versa*, is possible, but an expansion of plantation land to non-traded agriculture (food crops) land is not possible. Third, further expansion of plantation sectors can only be taken place by clearing forests; therefore, we can calculate the deforestation rate. Forth, each firm and household use primary inputs to produce outputs, there are no intermediate inputs. Fifth, farming household receives money income from working in plantation sectors and all household's income is spent for the consumption of goods from outside agriculture sector, there is no saving. Sixth, all plantation outputs are demanded by export market while all non-traded agricultural good is only demanded by farming household.

5.1. Household Behaviour

The farming household maximises utility by consuming composite "imported" good from urban sector (*M*); and home produced non-traded agriculture goods produced in its own field (Y_n). Imported good is a good produced by non-agriculture sector. We consider the composite import good has a fixed price P_m.

The consumption of imported good depends on household's income generated from hiring its labour supply to plantation firms (L_P) plantation land (Q_P). Non-traded agriculture good is self-produced and self-consumed by the household. Household is assumed to maximise utility under constant elasticity of substitution (CES) utility function.

$$MaxU(M,Y_n) = \psi(\delta M^{\rho} + (1-\delta)Y_n^{\rho})^{1/\rho} \tag{1}$$

since:

$$M = \frac{w.L_p}{P_m} \tag{2}$$

where, w is the wage rate in plantation sector, L_n is labour in non-traded agriculture, ψ, δ, and ρ are parameters. The production function of non-traded agriculture, which is a Cobb-Douglas function,

$$Y_n = Y_n(L_n, F_n) = \theta_n L_n^{\alpha_n} Q_n^{\beta_n} \tag{3}$$

where, Q_n is land used in non-traded agriculture, and $0 > \alpha_n, \beta_n > 1$. Also note that $L_n = \overline{L} - L_p$, where $\overline{L}$ is total labour in agriculture.

The household maximises utility (1) subject to (2) and (3) by choosing time allocated to model the household production, L_p. Taking the derivative of this utility with respect to L_p, we obtain the first order condition of L_p,

$$\delta w^{\rho} L_p^{\rho-1} P_m^{-\rho} - (1-\delta)\alpha_n \theta_n^{\rho} (\overline{L} - L_p)^{\alpha_n \cdot \rho - 1} Q_n^{\beta_n \cdot \rho} = 0 \tag{4}$$

This equation tells us the amount of labour that household wants to supply to plantation sector.

Note that the ratio $\frac{\rho}{1-\rho}$ is the elasticity of plantation labour supply curve (ε_{L_p}) and $\varepsilon_{L_p} > 0$. So that implies, $0 < \rho < 1$ to ensure the labour supply curve to have an upward slopping.

5.2. Plantation Firms

The production functions of plantation firms are assumed to have constant returns to scale under the Cobb-Douglas production function. Each unit of plantation outputs follows the production equation:

$$y_{p_i} = \theta_{p_i} L_{p_i}^{\ \alpha_{pi}} F_{p_i}^{\ \beta_{pi}} \quad (5)$$

where $p_i, i \in \{1,2\}$ indicate the other plantation firm, p_1, and the oil palm plantation firm, p_2. Likewise y_{p_i} indicates one unit of each type of plantation output.

Firms minimise cost subject to the available production technologies. Plantation outputs are obtained by combining labour (L_{p_i}) and land (Q_{p_i}).

$$MinC_{p_i}(w,q) = wL_{p_i} + qQ_{p_i} \quad (6)$$

subject to:

$$y_{p_i} = \delta_{p_i} L_{p_i}^{\ \alpha_{pi}} Q_{p_i}^{\ \beta_{pi}} \quad (7)$$

The firms' unit cost function is then,

$$c_{p_i}(w,q) = \theta_{p_i} w^{\alpha_{pi}} q^{\beta_{pi}} \quad (8)$$

where, c_{p_i} indicates the cost of producing one unit of each type of plantation output and θ_{p_i} indicates the inverse productivity of each firm.

The demand for labour for each firm is given by Shepard's Lemmas,

$$\frac{\partial c_{p_i}}{\partial w}(w,q) = \theta_{p_i} \alpha_{p_i} w^{\alpha_{pi}-1} q^{\beta_{pi}} = d_{L\,p_i} \quad (9)$$

Similarly, this first order condition can also be applied to derive demand for plantation land for each plantation firm:

$$\frac{\partial c_{p_i}}{\partial q}(w,q) = \theta_{p_i}\beta_{p_i} w^{\alpha_{p_i}} q^{\beta_{p_i}-1} = d_{Q\,p_i} \tag{10}$$

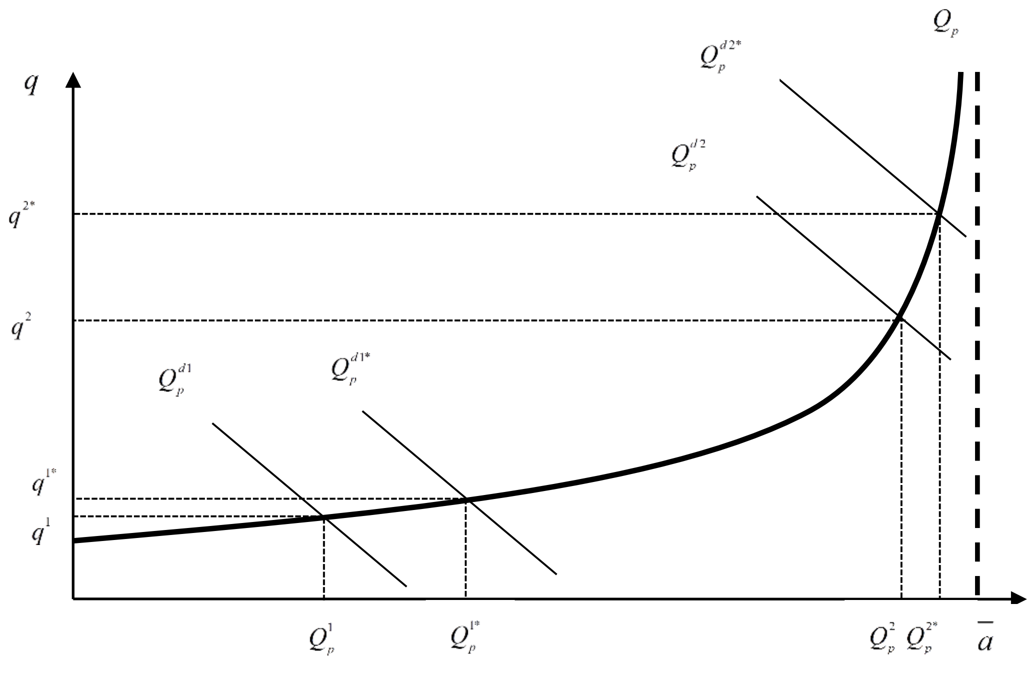
5.3. Plantation Land Supply

We model the plantation land supply as a function of land rental rate (q). This land supply model is adopted from Tabeau et al. (2006), van Meijl et al. (2006), and Banse et al. (2008). We make a slight adjustment to the model. In our model, we assume that the plantation land supply will be adjusted by converting forest land into plantation land. Therefore, the maximum potential land available for plantation $(\bar{a})$ is the sum of land already used in plantation and the total remaining forest cover. We also introduce P_q as a proxy of land clearing cost. The land supply is given as follows:

$$Q_p = \bar{a} - \frac{\bar{b}}{(q/P_q)^{\tau}} \tag{11}$$

where, Q_p is land supply in plantation sector, $\bar{a}$ is the optimum land available which is equal to total remaining forest and land already used in plantation, q is plantation land rental rate, $\bar{b}$ and τ are positive parameters to determine the land supply curve, and P_q is an exogenous cost associated with land clearing for plantation expansion.

Figure 3. Plantation land supply curve



The elasticity of land supply can be calculated as follows:

$$\varepsilon_{Q_p} = \frac{\tau \bar{b}}{\bar{a}(q/P_q)^{\tau} - \bar{b}}$$

In the case when land supply is elastic, a substantial increase in demanded land ($Q_p^1 \text{ to } Q_p^{1*}$) will only increase land rental rate slightly from $q^1 \text{ to } q^{1*}$. However, when land supply is inelastic, a small increase in demanded land ($Q_p^2 \text{ to } Q_p^{2*}$) will increase land rental rate substantially ($q^2 \text{ to } q^{2*}$). In an extreme case when land supply is completely inelastic, there will be no land expansion as demand just drives up land rental rates. In this case, the plantation industry can only be expanded by using existing land more intensively.

In our example, when total demanded by plantation land equals to Q_p^1 in Figure 3, total forest cover can be indicated by the distance between Q_p^1 and $\bar{a}$. A shift on plantation land demand curve from Q_p^{d1} to Q_p^{d1*} will reduce the size of forest by $Q_p^1 - Q_p^{1*}$, or, now, the remaining forest will equal to the distance between Q_p^{1*} and $\bar{a}$. This is how we model the forest cover loss.

5.4. World Demand

Suppose that the world consumes three types of goods non-palm oil plantation good (Y_{p_1}), palm oil (Y_{p_2}) and all other things (*x*). The world's expenditure can be indicated by a CES unit expenditure function:

$$e(P_{p_1}, P_{p_2}, P_x) = mu(\gamma_1 P_{p_1}{}^{\varphi} + \gamma_2 P_{p_2}{}^{\varphi} + \gamma_x P_x{}^{\varphi})^{\frac{1}{\varphi}} \tag{12}$$

Therefore, the utility can be defined as:

$$W_u = \frac{W_m}{e(P_{p_1}, P_{p_2}, P_x)} \tag{13}$$

where, W_m is the rest of the world's total income. Demand for other plantation and palm oil can be derived as:

$$W_{p_1}^d = \frac{\partial e(P_{p_1}, P_{p_2}, P_x)}{\partial P_{p_1}} W_u = mu\gamma_1 (\frac{e}{P_{p_1}})^{(1-\varphi)} W_u \tag{14}$$

$$W_{p_2}^d = \frac{\partial e(P_{p_1}, P_{p_2}, P_x)}{\partial P_{p_2}} W_u = mu\gamma_2 (\frac{e}{P_{p_2}})^{(1-\varphi)} W_u \tag{15}$$

The demand elasticity is $\frac{\partial \ln W_{p_i}^d}{\partial \ln p_i} = \varphi - 1$.

5.5. Market Clearing

Zero profit

For both plantation firms, production will be maximised when zero profit condition is attained. The zero profit conditions are,

$$c_{p_1}(w,q) = P_{p_1} \tag{16}$$

$$c_{p_2}(w,q) = P_{p_2} \tag{17}$$

Labour market clearing

Market for plantation labour is cleared when total demand for labour in plantation equals to the sum of labour demand in oil palm plantation and labour demand in other plantation sectors. Y_{p_i} indicates total real output in plantation sectors.

$$\frac{\partial c_{p_1}}{\partial w}(w,q).Y_{p_1} + \frac{\partial c_{p_2}}{\partial w}(w,q).Y_{p_2} = L_p \tag{18}$$

And L_p indicates total labour supplied by farming household as indicated in equation (4).

Land market clearing

The land market for plantation is cleared when total land demanded by each plantation firm equals to the total supply for land. Or,

$$\frac{\partial c_{p_1}}{\partial q}(w,q)Y_{p_1} + \frac{\partial c_{p_2}}{\partial q}(w,q)Y_{p_2} = Q_p \tag{19}$$

Note that land is not only used by oil palm plantation, but also by other plantation. Here, an expansion of oil palm plantation land can occur either by reducing forest land, or by reducing already established plantation land.

Specifically, oil palm expansion in Indonesia has been largely associated with forest conversion. However, replacing other types of plantation estates to oil palm estates is also a common practise in Indonesia and Malaysia (Agus et al., 2013). A study by Koh and Wilcove (2008) has estimated that at least 1.3 million ha of other commercial crops had been decreased during 1990 to 2005, that accounts for 44 percent of oil palm expansion in Indonesia.

Several studies also show the conversion of other plantation crops to oil palm in smallholding farming in several places in Indonesia, in order to generate more income, like Feintrenie et al. (2010a), Feintrenie et al. (2010b), Rist et al. (2010), and (Sayer et al., 2012).

World's market clearing

The world's market for other plantation and palm oil will be cleared when demand equals supply or:

$$W_{p_1}^d = Y_{p_1} \tag{20}$$

World's market clearing condition:

$$P_{p_1}W_{p_1}^d + P_{p_2}W_{p2}^d = P_{p_1}Y_{p_1} + P_{p_2}Y_{p_2} \tag{21}$$

The following is the summary of the model.

6. Data and Calibrations

This model will be mainly based on the Indonesian Social Accounting Matrix 2008 (SAM) and the Indonesian Input-Output tables updating 2008 (IO). Both are published by the Indonesian Central Bureau of Statistics (BPS). SAM has 24 sectors, while IO has 66 sectors. In this chapter, we consider crop agriculture only which listed as sector 28 and sector 29 in SAM and sector 1 to sector 17 in IO. All data in SAM and IO are in Indonesian Rupiah

(IDR). The crop agriculture sector is then broken down into three sub sectors: non-traded agriculture (food crops), oil palm plantation, and other plantation.

Data for agricultural workers and their wage rates is obtained from a SAM (BPS, 2010). Data for agricultural land use is obtained from Indonesian Ministry of Agriculture (MoA, 2015) and data on forest cover is obtained from Food and Agriculture Organization (FAOSTAT, 2015).

Table 4 summarises the structure of crop agriculture in Indonesia. Non-traded agriculture accounts for almost 75% of total crop agriculture. There are more than 30 types of crops in this category including grains, tubes, fruits and vegetables. Other plantation crops cover more than 20 commodities and account for approximately 17% of total crop value; while oil palm plantation accounts for 8%. The lists of plantation crops are available in Table A1.2 in Appendix 1.

The shares of labour value are high in all type of crops, more than 90% for non-traded agriculture and more than 80% for both types of plantation crops.

Table 4. Structure of crop agriculture in Indonesia, 2008 (Trillion IDR)

No.	Sub-sector	Value added	Labour value	Land value
1.	Non-traded agriculture *(n)*	377.52	356.47 (94.42)	21.05 (5.58)
2.	Other plantation *(p_1)*	86.27	72.00 (83.46)	14.27 (16.54)
3.	Oil palm plantation *(p_2)*	42.54	34.33 (80.71)	8.21 (19.29)

Source: author's calculation based on IO (BPS, 2009), SAM (BPS, 2010) and MoA (2015).
Note: numbers in the parentheses indicate percentage shares.

The elasticities estimates used in this model are based on some previous researches. According to van Meijl et al. (2006) the elasticities of land supply in developing countries vary between 0.5 and 3. We proceed with the land supply elasticity of 3. The elasticity of labour supply is set equal to 0.5 following Rochjadi and Leuthold (1994). For palm oil demand, we set the elasticity to -2.50. Most of the researches find that palm oil demand to be elastic (for detailed references palm oil demand elasticities see Table A1.1 in appendix 1).

7. Experiment Design

As we previously mentioned in introduction, Indonesia's palm oil production has grown by around 10 percent annually. Our objective is then to increase the production of palm oil in Indonesia by 10 percent in the following year. The palm oil industry expansion can be driven by three types of potential causes, namely: growth in foreign demand; land use policy; and productivity growth.

We will also consider the combination of those three scenarios as the mixed scenario. In this scenario, we assume that the growth in demand explains 50 percent of the overall increase in palm oil production and the productivity growth of the palm oil industry is set at 2 percent level. We then set the change in $\bar{b}$ in the land supply equation such that palm oil production increases by 10 percent.

Table 5 reports the exogenous shocks we set in the simulations. The shocks are all designed so that in our equilibrium, output of palm oil increases by 10 percent.

Table 5. Exogenous shocks (%)

Exogenous shock	
Scenario 1: demand	
Demand share of palm oil (γ_2)	19.62
Scenario 2: land supply	
Land supply parameter ($\bar{b}$)	-27.16
Scenario 3: productivity	
Palm oil inverse productivity (θ_2)	-4.44
Scenario 4: mixed	
Demand share of palm oil (γ_2)	9.81
Palm oil productivity(θ_2)	2.00
Land supply parameter ($\bar{b}$)	-0.78

8. Results

We will discuss the impacts of oil palm plantation expansion on wage, labour, and land use changes. More complete numerical results are available in Table A2.1 to A2.4 in Appendix 2.

8.1. Wage, Labour and Income

By increasing palm oil production by 10 percent, demands for plantation labour in all scenarios increase. The increases in labour demand then triggers wage rate increases.

Consider the demand shock scenario (scenario 1) as our base scenario. In Table 6 we can see, first, that this scenario gives the highest increases in wage rate, labour demand and nominal income. As by definition, nominal income is a multiplication of wage rate and labour demand. In this scenario, the wage rate increases by 3.87 percent, demand for plantation labour increases by 1.56 percent, and nominal income increases by 5.49 percent.

The land supply scenario (scenario 2) also produces relatively large increases in wage rate, labour demand and income. Wage rate, labour demand, and income increase by 3.38 percent, 1.37 percent, and 4.80 percent, respectively.

However, when the increase in palm oil production is induced by the productivity growth (scenario 3), we find that it only gives a very limited impact on labour market. Table 6 shows that in this scenario, wage rate increases by only 0.82 percent, labour demand by only 0.33 percent, and nominal income by only 1.15 percent.

In scenario 4, when we combine demand, productivity and land policy shocks, we find that wage rate goes up in a relatively moderate level at 2.44 percent. While labour demand and nominal income increase by more than in scenario 3 but less than in scenario 1 and in scenario 2 at 0.99 percent and 3.45 percent, respectively.

Table 6. Changes in plantation wage rate, plantation labour demand and income [a]

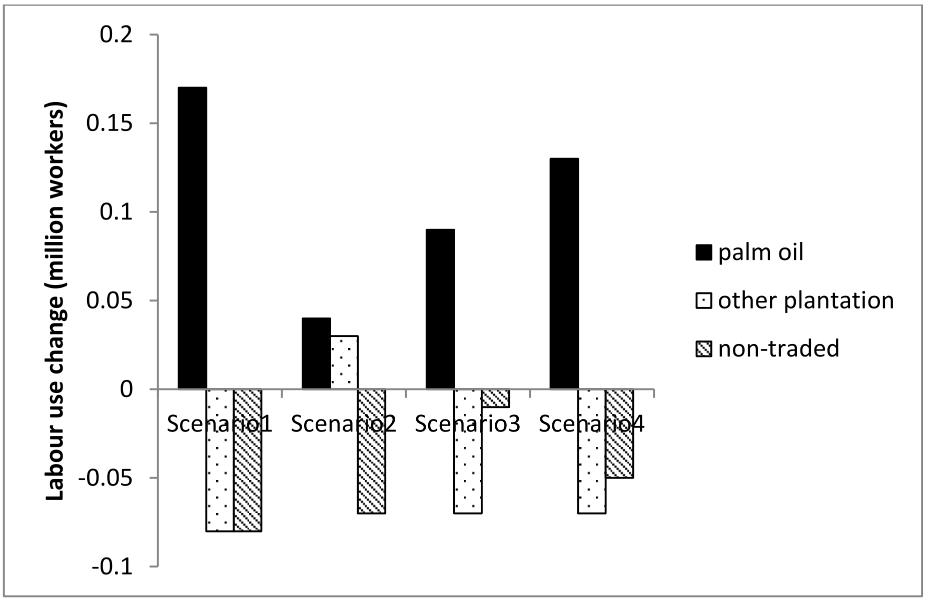
Endogenous variable	**Base year**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Plantation wage rate	19.83	20.60 (3.87)	20.51 (3.39)	20.00 (0.82)	20.32 (2.44)
Total plantation labour	5.36	5.44 (1.56)	5.43 (1.37)	5.38 (0.33)	5.41 (0.99)
Nominal income	106.33	112.17 (5.49)	111.44 (4.80)	107.56 (1.15)	110.00 (3.45)

Note: [a] numbers in the parentheses indicate percentage change. Plantation wage rate is in million IDR/worker/year, plantation labour is in million workers, and nominal wage income is in Trillion IDR.

From household function, we know that farmers can work in plantation sectors or on their own lands to produce non-traded agriculture goods. We assume that job in plantation is taken first, indicated by $L_n = \bar{L} - L_p$, where L_n is labour supply in non-traded agriculture, $\bar{L}$ is total labour endowment in agriculture sector, and L_p is labour supply in plantation. In Figure 4 we can see that the numbers of workers in non-traded agriculture decrease in all scenarios. On the contrary, the numbers of workers who work in oil palm plantation increase in all scenarios. While; for other plantation, demand for labour only increases in the land supply scenario.

Overall, our base scenario (scenario 1) gives the highest impact on shifting labours from non-traded agriculture to plantation sector. In contrast, the productivity scenario (scenario 3) gives the lowest impact. The numbers of workers who shift from non-traded agriculture to plantation sector are 80 thousand, compared to only 10 thousand in scenario 3.

Figure 4. Effects of exogenous shocks on labour use change [a]



In Table 6, we see that demand for plantation labours increase in all scenarios. However, Figure 4 shows that the increases in plantation labour demands are caused mostly by the increases in labour demands in oil palm plantation sector only (except for scenario 2). The decreases in the demand for labours in other plantation indicate that this industry is contracting, except for scenario 2.

The levels of labour demand changes in oil palm plantation also vary across scenarios. The number of oil palm plantation workers increase from the largest at 170 thousand in scenario 1 to the least at 40 thousand workers in scenario 2.

8.2. Land Use

Most of the literatures on Indonesian palm oil industry put emphasise on land use change as it is generally accepted as the driving factor of forest loss. In this model, we also calculate the impact of oil palm plantation expansion on land use and forest cover changes in Indonesia. For the simplicity of the model, we only use forest cover data in general. We do not classify forest into several categories as addressed by many studies, particularly studies on

Geographical or Ecological sciences. Data on forest cover is obtained from FAO (FAOSTAT, 2015).

Table 7 shows the impacts of exogenous shocks on plantation land rental rates and plantation land use changes. From this table, we can see that; first, land rental rates increase in all scenarios, except in land supply scenario (scenario 2); second, total plantation lands expand in all scenarios.

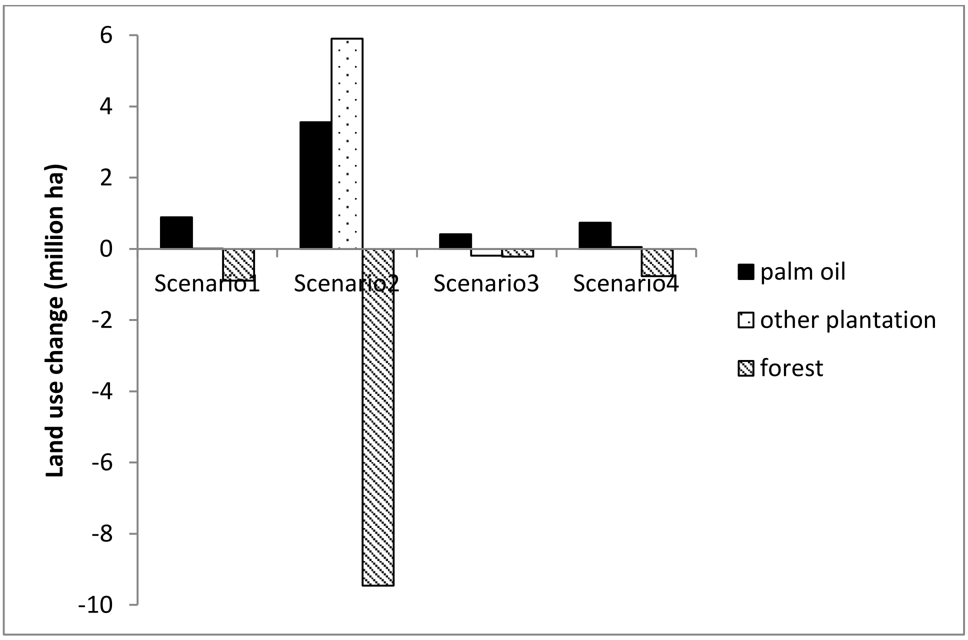
Table 7. Changes in plantation land rental rate and total plantation land demand [a]

Endogenous variable	Base year	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Plantation land rental rate	1.11	1.13 (1.50)	0.80 (-28.62)	1.12 (0.36)	1.11 (0.04)
Total plantation land	20.16	21.06 (4.44)	29.63 (46.92)	20.38 (1.08)	20.94 (3.82)

Note: [a] numbers in the parentheses indicate percentage change. Plantation land rental rate is in million IDR/ha/year, and plantation land is in million ha.

As we explain in the modelling section, the expansion of oil palm plantation can be taken place both in already established plantation lands and in the forest. The negative growth of other plantation lands in Figure 5 can be seen as converting other plantation lands to oil palm plantation lands. The conversion of other plantation land to oil palm plantation land only occurs in the productivity scenario (scenario 3). In this scenario, other plantation land shrinks by 1.46 percent or 0.2 million hectares.

Figure 5. Effects of exogenous shocks on land use change



The expansions of oil palm plantation lands purely occur at the expense of forest cover in all other three scenarios. This means that both oil palm and other plantation lands expand. The increases in other plantation lands are very small at 0.01 and 0.05 million hectares in scenario 1 and scenario 4, respectively, compared to 5.9 million hectares in scenario 2.

Thus even though palm oil production increases by 10 percent across all scenarios, the results of land use changes varied very substantially. As expected, oil palm plantation lands expand very largely in the land supply scenario. These large expansions also happen to other plantation lands since they share the same land supply curve and face the same decreasing land rental rate as oil palm plantation. As a consequence, forest suffered the most in this scenario. Forest loss is 9.5 million hectares.

In the demand shock scenario, palm oil requires 0.9 million hectares to expand its production by 10 percent. This number is lower than the land supply shock scenario (3.6 million hectares), but higher than productivity scenario (0.4 million hectares) and mixed scenario (0.7 million hectares).

The forest cover loss is 0.9 million ha in the demand shock scenario. The productivity shock scenario may preserve forest the best compared to other scenarios. Forest only experiences small disruption at around 0.2 million hectares in this scenario. In contrast, forest loses 9.5 million hectares in the land supply shock scenario. This scenario gives the worst effect on forest cover. Finally, in our mixed shock scenario, we find that forest cover loss is 0.8 million hectares, it is slightly less than the demand shock scenario and larger than the productivity shock scenario.

8.3. Sensitivity Analysis

A sensitivity analysis was conducted by changing the elasticities as shown in Table 8. Elasticities used in this model are based on some previous researches. We set land supply elasticity equals to 3 ($\tau = 0.632$) when land supply is elastic and 0.5 ($\tau = 0.105$) when land supply is inelastic. For labour supply, we set labour supply elasticity equals to 2 ($\rho = 0.667$) when elastic and 0.5 ($\rho = 0.333$) when inelastic. In all cases we set the demand elasticity for palm oil equals to -2.50 ($\varphi = -1.5$). The results we show in the earlier section are based on case 1.

Again, for all scenarios and cases, we set the palm oil industry to grow by 10 percent. The levels of exogenous shocks across scenarios based on four cases are presented in Table 8.

Table 8. Exogenous shocks (%)

Exogenous shock	Case 1	Case 2	Case 3	Case 4
	$\tau = 0.63$ $\rho = 0.33$ $\varphi = -1.50$	$\tau = 0.63$ $\rho = 0.67$ $\varphi = -1.50$	$\tau = 0.105$ $\rho = 0.67$ $\varphi = -1.50$	$\tau = 0.105$ $\rho = 0.33$ $\varphi = -1.50$
Scenario 1: demand				
Demand share of palm oil (γ_2)	19.62	13.76	15.09	23.39
Scenario 2: land supply				
Land supply parameter ($\overline{b}$)	-27.16	-22.83	-10.73	-13.00
Scenario 3: productivity				
Palm oil inverse productivity (θ_2)	-4.44	-4.23	4.32	4.51
Scenario 4: mixed				
Demand share of palm oil (γ_2)	9.81	6.88	7.55	11.70
Palm oil productivity(θ_2)	2.00	2.00	2.00	2.00
Land supply parameter ($\overline{b}$)	-0.78	-0.525	-0.22	-0.32

Source: all parameters are author's calculation based on elasticities in van Meijl et al. (2006) and Rochjadi and Leuthold (1994). For detailed sources of palm oil demand elasticities see Table A1.1 in appendix 1.

The changes of the elasticities clearly affect the magnitude of the results, but in general, do not alter the ordering of the results. For example, across all cases, the levels of income changes are high in the demand shock scenario and the land supply shock scenario. The productivity shock scenario produces the lowest increase in income changes across all cases. Similarly, the mixed shock scenario affects the level of income moderately.

For land use changes, across all cases, the land supply shock scenario gives the worst impacts to forest cover losses. The demand shock scenario and the mixed shock scenario produce relatively moderate impacts on forest losses. And finally, all cases in the productivity shock scenario give the best results in term of forest losses.

More complete simulation results across scenarios and across cases are available in Table A2.1-Table A2.4 in Appendix 2.

9. Conclusion

Indonesia's palm oil industry has expanded significantly in recent decades with an annual growth rate of more than 10 percent during 1990-2013. This growth is driven both by the increase in demand for food and other industrial purposes, including biodiesel. The palm oil industry is an important economic driver and creates employment, especially in rural areas. Despite its economic importance, the palm oil industry is considered to be a major cause of deforestation, as oil palm plantation expansion is highly associated with forest cover loss.

We consider three types of potential causes for the expansion of palm oil, namely; growth in foreign demand; land use policies; and productivity growth. The results suggest that the impact of palm oil growth on incomes and deforestation depend on the cause.

The land policy scenarios produce a large impact in forest losses and positive impact on labour income changes, but if they prime cause is simply growth in foreign demand we find that there is a less severe impact on forest cover loss and a higher impact on labour incomes.

If productivity growth is included then there is less impact on forest cover but also little impact on wage incomes of labour. In this scenario, because the land and labour are more productive, there will be less forest conversion to oil palm plantation and less labour shifting from home produced agriculture (non-traded agriculture) to plantation sectors.

Finally, we can say that the results from our last scenario which combines all of these factors are located in between the demand shock scenario and the productivity shock scenario. We find that it produces a slightly less impact on forest loss compared to the demand shock scenario but higher than the productivity shock scenario. In term of labour income changes, the mixed shock scenario gives relatively moderate impact, which is less than the demand shock scenario, but higher than the productivity shock scenario.

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Appendix 1. Data and calibration

Table A1.1. Summary of demand elasticity for Indonesian palm oil

No.	author	Own-price elasticity		note
1.	Suryana (1986)*	US[g]	-1.46	*cited in (Goddard and Glance, 1989)
		US[h]	-1.14	[g] unrestricted AIDS model
		US[i]	-1.57	[h] AIDS model with homogeneity imposed
		Japan[g]	-0.89	[i] corrected for autocorrelation (lag=1)
		Japan[h]	-1.16	
		Japan[i]	-0.90	
2.	Senteri (1988)	Short run	-4.144	
		Long run	-11.673	
3.	Goddard and Glance (1989)	US	-1.47	
		Canada	-0.8	
		Japan	-0.34	
4.	Larson (1990)	Habit model	-1.6	
		No- habit model	-1.8	
5.	Yen and Chern (1992)	Model I	-1.5	Full model with serially correlated errors
		Model II	-1.192	Translog with serially correlated errors
		Model III	-1.298	AIDS with serially correlated errors
		Model IV	-3.224	Full model with serially independent errors
		Model GG	-1.47	Goddard and Glance
6.	Ernawati et al. (2006)	India*	-2.74	*price ratio of palm oil and soybean oil
		China	-1.49	
		Europe	-0.42	
		ROW	-2.23	
7.	Rifin (2010)	ROW short run	-0.845	
		ROW long run	-1.960	
8.	Villoria et al. (2013)	Indonesia*	-1.01	*used in GTAP
		Malaysia*	-2.93	
9.	Kojima et al. (2014)	Palm oil	-1.24	

Table A1.2. List of crop land use, 2008

No.	Type of crops	Area
I.	**Food crops**	
1.	Avocados	19,802
2.	Bananas	107,791
3.	Beans, dry	278,139
4.	Cabbages and other brassicas	61,540
5.	Carrots and turnips	24,640
6.	Cassava	1,204,933
7.	Cauliflowers and broccoli	8,898
8.	Chillies and peppers, green	211,566
9.	Cucumbers and gherkins	55,795
10.	Eggplants (aubergines)	48,434
11.	Fruit, fresh nes	75,608
12.	Fruit, tropical fresh nes	231,849
13.	Garlic	1,922
14.	Ginger	87,117.17
15.	Groundnuts, with shell	633,922
16.	Leeks, other alliaceous vegetables	52,101
17.	Maize	4,001,724
18.	Mangoes, mangosteens, guavas	210,945
19.	Melons, other (inc.cantaloupes)	8,533
20.	Mushrooms and truffles	636.9
21.	Onions, dry	91,339
22.	Oranges	68,673
23.	Papayas	9,388
24.	Pineapples	14,271
25.	Potatoes	64,151
26.	Pumpkins, squash and gourds	12,431
27.	Rice, paddy	12,327,425
28.	Soybeans	590,956
29.	Spinach	44,711
30.	Sweet potatoes	174,561
31.	Tomatoes	53,128
32.	Vegetables, assorted	258,516

33.	Watermelons	27,639
	Total Food crops	**21,063,085.07**
II.	**Plantations**	
1.	Areca nuts	137,325
2.	Bastfibres, other	56
3.	Cashew nuts, with shell	573,721
4.	Castor oil seed	5,274
5.	Cinnamon (canella)	101,961
6.	citronella	20,111
7.	Cloves	456,471
8.	Cocoa, beans	1,425,216
9.	Coconuts	3,783,074
10.	Coffee, green	1,295,111
11.	Kapok fruit	177,737
12.	Manila fibre (abaca)	-
13.	Nuts, nes	216,906
14.	Nutmeg, mace and cardamoms	86,162
15.	patchouli	22,132
16.	Pepper (piper spp.)	183,082
17.	Rubber, natural	3,424,217
18.	Seed cotton	11,729
19.	Sisal	431
20.	Siwalan	26,854
21.	Spices, nes	4,557
22.	Sugar cane	436,505
23.	Sugar crops, nes	58,874
24.	Tea	127,712
25.	Tobacco, unmanufactured	196,627
26.	Vanilla	30,006
	Total non-palm oil plantation	**12,801,851**
27.	Oil, palm fruit	7,363,847
	Total Plantation	**20,165,698**
	TOTAL CROP LAND	**41,228,783.07**

Source:MoA (2015), some crops are aggregated.

Table A1.3 Forest cover

Year	Forest cover (thousand ha)
1990	118545
1991	116631.4
1992	114717.8
1993	112804.2
1994	110890.6
1995	108977
1996	107063.4
1997	105149.8
1998	103236.2
1999	101322.6
2000	99409
2001	99098.6
2002	98788.2
2003	98477.8
2004	98167.4
2005	97857
2006	97172
2007	96487
2008	95802
2009	95117
2010	94432
2011	93747
2012	93062

Source: FAOSTAT (2015)

Appendix 2. Simulation results

Table A2.1 to A2.4 summarise the effects of exogenous shocks on several selected variables in Indonesian crop agriculture sectors. The results reported both in absolute values and percentage changes.

Table A2.1. Results for the demand shock scenario

Variable		**Base (2008)**	**Case 1** $\tau = 0.63$ $\rho = 0.33$ $\varphi = -1.50$	**Case 2** $\tau = 0.63$ $\rho = 0.67$ $\varphi = -1.50$	**Case 3** $\tau = 0.105$ $\rho = 0.67$ $\varphi = -1.50$	**Case 4** $\tau = 0.105$ $\rho = 0.33$ $\varphi = -1.50$
Exogenous shock:						
palm oil demand share (γ_2)	Per cent		19.62	13.76	15.09	23.39
Results:						
Price						
Palm oil	IDR	1	1.03 (3.41)	1.01 (1.35)	1.02 (1.83)	1.05 (4.70)
Other plantation	IDR	1	1.03 (3.48)	1.01 (1.36)	1.02 (1.79)	1.05 (4.70)
Real output						
Palm oil	Tril. IDR	42.54	46.80 **(10.01)**	46.79 **(10.01)**	46.79 **(10.01)**	46.79 **(10.00)**
Other plantation	Tril. IDR	86.27	84.66 (-1.86)	85.16 (-1.29)	84.99 (-1.49)	84.54 (-2.01)
Non traded agriculture	Tril. IDR	377.52	376.31 (-0.32)	375.74 (-0.47)	375.59 (-0.51)	376.06 (-0.39)
Factor income						
Plantation wage	Mil. IDR/wk/yr	19.83	20.60 (3.87)	20.12 (1.42)	20.14 (1.54)	20.76 (4.69)
Plantation land rental	Mil. IDR/ha/yr	1.11	1.13 (1.50)	1.13 (1.06)	1.15 (3.03)	1.17 (4.77)
Wage income						
Nominal wage income	Tril. IDR	106.33	112.17 (5.49)	110.32 (3.75)	110.66 (4.06)	113.42 (6.66)
Labour						
Oil palm	Mil. wks	1.73	1.90 (9.52)	1.90 (9.93)	1.91 (10.32)	1.90 (10.02)
Other plantation	Mil. wks	3.63	3.55 (-2.24)	3.58 (-1.34)	3.59 (-1.25)	3.56 (-1.99)
Total plantation	Mil. wks	5.36	5.44 (1.56)	5.48 (2.30)	5.49 (2.49)	5.46 (1.88)
Non traded agriculture	Mil. wks	24.67	24.59 (-0.34)	24.55 (-0.50)	24.54 (-0.54)	24.57 (-0.41)
Land						
Oil palm	Mil. ha	7.36	8.25 (12.08)	8.12 (10.33)	8.01 (8.72)	8.10 (9.94)
Other plantation	Mil. ha	12.80	12.81 (0.05)	12.68 (-0.99)	12.46 (-2.68)	12.54 (-2.07)
Total plantation	Mil. ha	20.16	21.06 (4.44)	20.80 (3.15)	20.47 (1.49)	20.63 (2.32)
Forest land	Mil. ha	95.80	94.91 (-0.94)	95.17 (-0.66)	95.50 (-0.31)	95.33 (-0.49)

Note: numbers in the parentheses indicate percentage change

Table A2.2. Results for the plantation land supply shock scenario

Variable		Base (2008)	Case 1	Case 2	Case 3	Case 4
			$\tau = 0.63$	$\tau = 0.63$	$\tau = 0.105$	$\tau = 0.105$
			$\rho = 0.33$	$\rho = 0.67$	$\rho = 0.67$	$\rho = 0.33$
			$\varphi = -1.50$	$\varphi = -1.50$	$\varphi = -1.50$	$\varphi = -1.50$
Exogenous shock:						
Land supply parameter ($\bar{b}$)	Per cent		-27.16	-22.83	-10.73	-13.00
Results:						
Price						
Palm oil	IDR	1	0.96 (-3.74)	0.96 (-3.74)	0.96 (-3.74)	0.96 (-3.74)
Other plantation	IDR	1	0.97 (-2.76)	0.97 (-2.96)	0.97 (-2.96)	0.97 (-2.76)
Real output						
Palm oil	Tril. IDR	42.54	46.79 **(10.00)**	46.79 **(10.00)**	46.79 **(10.00)**	46.79 **(10.00)**
Other plantation	Tril. IDR	86.27	92.51 (7.23)	92.99 (7.79)	92.99 (7.79)	92.51 (7.23)
Non traded agriculture	Tril. IDR	377.52	376.46 (-0.28)	375.14 (-0.63)	375.14 (-0.63)	376.46 (-0.28)
Factor income						
Plantation wage	Mil. IDR/wk/yr	19.83	20.50 (3.39)	20.21 (1.90)	20.21 (1.90)	20.50 (3.39)
Plantation land rental	Mil. IDR/ha/yr	1.11	0.80 (-28.61)	0.85 (-24.15)	0.85 (-24.14)	0.80 (-28.60)
Wage income						
Nominal wage income	Tril. IDR	106.33	111.44 (4.80)	111.67(5.02)	111.67 (5.02)	111.43 (4.80)
Labour						
Oil palm	Mil. wks	1.73	1.77 (2.42)	1.80 (3.92)	1.80 (3.92)	1.77 (2.42)
Other plantation	Mil. wks	3.63	3.66 (0.86)	3.73(2.66)	3.73 (2.66)	3.66 (0.86)
Total plantation	Mil. wks	5.36	5.43 (1.37)	5.53 (3.06)	5.53 (3.06)	5.43 (1.37)
Non traded agriculture	Mil. wks	24.67	24.60 (-0.30)	24.51 (-0.67)	24.51 (-0.67)	24.60 (-0.30)
Land						
Oil palm	Mil. ha	7.36	10.92 (48.31)	10.28 (39.58)	10.28 (39.58)	10.92 (48.31)
Other plantation	Mil. ha	12.80	18.70 (46.06)	17.65 (37.89)	17.65 (37.89)	18.70 (46.05)
Total plantation	Mil. ha	20.16	29.62 (46.88)	27.93 (38.51)	27.93 (38.51)	29.62 (46.88)
Forest land	Mil. ha	95.80	86.35 (-9.87)	88.04 (-8.11)	88.04 (-8.11)	86.35 (-9.87)

Note: numbers in the parentheses indicate percentage change

Table A2.3. Results for the productivity shock scenario

Variable		Base (2008)	Case 1 $\tau = 0.63$ $\rho = 0.33$ $\varphi = -1.50$	Case 2 $\tau = 0.63$ $\rho = 0.67$ $\varphi = -1.50$	Case 3 $\tau = 0.105$ $\rho = 0.67$ $\varphi = -1.50$	Case 4 $\tau = 0.105$ $\rho = 0.33$ $\varphi = -1.50$
Exogenous shock:						
Palm oil inverse productivity (θ_2)	Per cent		-4.44	-4.23	-4.32	-4.51
Results:						
Price						
Palm oil	IDR	1	0.96 (-3.74)	0.96 (-3.74)	0.96 (-3.74)	0.95 (-3.74)
Other plantation	IDR	1	1.01 (0.74)	1.01 (0.51)	1.01 (0.59)	1.01 (0.80)
Real output						
Palm oil	Tril. IDR	42.54	46.80 **(10.01)**	46.79 **(10.01)**	46.79 **(10.01)**	46.79 **(10.00)**
Other plantation	Tril. IDR	86.27	84.69 (-1.83)	85.18 (-1.27)	85.01 (-1.46)	84.57 (-1.98)
Non traded agriculture	Tril. IDR	377.52	377.26 (-0.07)	376.85 (-0.18)	376.89 (-0.17)	377.27 (-0.07)
Factor income						
Plantation wage	Mil. IDR/wk/yr	19.83	20.00 (0.82)	19.94 (0.53)	19.93 (0.50)	20.00 (0.78)
Plantation land rental	Mil. IDR/ha/yr	1.11	1.12 (0.36)	1.12 (0.42)	1.13 (1.06)	1.12 (0.93)
Wage income						
Nominal wage income	Tril. IDR	106.33	107.56 (1.15)	107.81(1.39)	107.72 (1.31)	107.50 (1.09)
Labour						
Oil palm	Mil. wks	1.73	1.82 (5.03)	1.82 (5.33)	1.82 (5.36)	1.82 (5.07)
Other plantation	Mil. wks	3.63	3.56 (-1.91)	3.58 (-1.28)	3.58 (-1.37)	3.56 (-1.95)
Total plantation	Mil. wks	5.36	5.38 (0.33)	5.41 (0.85)	5.40 (0.80)	5.38 (0.32)
Non traded agriculture	Mil. wks	24.67	24.66 (-0.07)	24.63 (-0.19)	24.63 (-0.17)	24.66 (-0.07)
Land						
Oil palm	Mil. ha	7.36	7.77 (5.51)	7.77 (5.45)	7.72 (4.78)	7.73 (4.91)
Other plantation	Mil. ha	12.80	12.61 (-1.46)	12.65 (-1.17)	12.56 (-1.92)	12.53 (-2.10)
Total plantation	Mil. ha	20.16	20.38 (1.08)	20.42 (1.25)	20.27 (0.53)	20.26 (0.46)
Forest land	Mil. ha	95.80	95.58 (-0.23)	95.55 (-0.26)	95.70 (-0.11)	95.71 (-0.10)

Note: numbers in the parentheses indicate percentage change

Table A2.4. Results for the mixed shock scenario

Variable		Base (2008)	Case 1 $\tau = 0.63$ $\rho = 0.33$ $\varphi = -1.50$	Case 2 $\tau = 0.63$ $\rho = 0.67$ $\varphi = -1.50$	Case 3 $\tau = 0.105$ $\rho = 0.67$ $\varphi = -1.50$	Case 4 $\tau = 0.105$ $\rho = 0.33$ $\varphi = -1.50$
Exogenous shock:						
palm oil demand (γ_2)	Per cent		9.81	6.88	7.55	11.70
Palm oil inverse productivity (θ_2)	Per cent		2.00	2.00	2.00	2.00
Land supply parameter ($\overline{b}$)	Per cent		-0.78	-0.525	-0.22	-0.32
Results:						
Price						
Palm oil	IDR	1	1.00 (-0.07)	0.99 (-1.14)	0.99 (-0.90)	1.01 (0.61)
Other plantation	IDR	1	1.02 (2.04)	1.01 (0.89)	1.01 (1.11)	1.03 (2.69)
Real output						
Palm oil	Tril. IDR	42.54	46.80 **(10.01)**	46.79 **(10.00)**	46.79 **(10.00)**	46.79 **(10.00)**
Other plantation	Tril. IDR	86.27	84.85 (-1.64)	85.27 (-1.16)	85.16 (-1.29)	84.72 (-1.79)
Non traded agriculture	Tril. IDR	377.52	376.75 (-0.20)	376.26 (-0.33)	376.19 (-0.35)	376.62 (-0.24)
Factor income						
Plantation wage	Mil. IDR/wk/yr	19.83	20.32 (2.44)	20.03 (1.00)	20.04 (1.06)	20.40 (2.85)
Plantation land rental	Mil. IDR/ha/yr	1.11	1.11 (0.02)	1.12 (0.34)	1.13 (1.40)	1.14 (1.93)
Wage income						
Nominal wage income	Tril. IDR	106.33	110.00 (3.45)	109.13 (2.63)	109.29 (2.78)	110.62 (4.03)
Labour						
Oil palm	Mil. wks	1.73	1.86 (7.31)	1.86 (7.66)	1.87 (7.87)	1.86 (7.62)
Other plantation	Mil. wks	3.63	3.56 (-2.02)	3.58 (-1.27)	3.59 (-1.23)	3.56 (-1.93)
Total plantation	Mil. wks	5.36	5.41 (0.99)	5.45 (1.62)	5.45 (1.71)	5.42 (1.15)
Non traded agriculture	Mil. wks	24.67	24.62 (-0.22)	24.59 (-0.35)	24.58 (-0.37)	24.61 (-0.25)
Land						
Oil palm	Mil. ha	7.36	8.09 (9.90)	7.98 (8.37)	7.92 (7.51)	8.00 (8.58)
Other plantation	Mil. ha	12.80	12.85 (0.34)	12.72 (-0.62)	12.60 (-1.56)	12.67 (-1.05)
Total plantation	Mil. ha	20.16	20.94 (3.83)	20.70 (2.67)	20.52 (1.75)	20.66 (2.47)
Forest land	Mil. ha	95.80	95.03 (-0.81)	95.26 (-0.56)	95.45 (-0.37)	95.30 (-0.52)

Note: numbers in the parentheses indicate percentage change