THE PALM OIL REVOLUTION IN ASIA

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Joanne Catherine Gaskell
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Rosamond Naylor, Primary Adviser

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Walter Falcon, Co-Adviser

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Harold Mooney

Approved for the Stanford University Committee on Graduate Studies.

Patricia J. Gumport, Vice Provost Graduate Education

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Joanne Gaskell
Litchfield, Maine

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Chapter 1 The vegetable oils landscape: changes in diets, changes in land-use

Global vegetable oils markets are re-shaping the world food system. No other sector of the world food economy is as dynamic on such a large scale. Since 1970, the area planted to oil crops has expanded by one hundred and thirty five million hectares, while the area planted to cereals has increased by only seven million hectares. The vegetable oils sector comprises, in order of importance by volume: palm oil, soybean oil, rapeseed oil, and a host of more minor oils – sunflower oil, cottonseed oil, groundnut oil, coconut oil, and olive oil. When one considers the area of the earth's surface that is appropriated for growing food, oil crops, as a group, now occupy more cropland than rice, wheat, or maize (see figure 1-1). The rise in vegetable oil production – and palm oil production in particular – affects what the world eats, who farms, and which landscapes are transformed for growing food.

As a category, vegetable oils are characterized by a high degree of substitutability in consumption. Olive oil has a distinguishing taste that contributes to its relatively high price, but other oils trade within a narrow price band (see figure 1-2). Once they have been refined, bleached, and deodorized, vegetable oils serve broadly the same set of purposes. Slightly different fatty acid profiles produce slight differences in quality, depending on the application. Saturated vegetable oils are generally better for baking, for example, while the smoke point determines whether vegetable oils are better for high-temperature frying or raw consumption.

Though vegetable oils have only slight differences in their consumable properties, vegetable oils differ significantly in how they are produced. Rapeseed (also known as Canola) grows exclusively in temperate regions, while oil palm (*Elaeis guineensis*) requires the warm, wet climate found in lowlands near the equator. Soybeans straddle both temperate and tropical climates, growing well in the US Midwest, the Argentine pampas, and also, thanks to soil remediation and disease control techniques, in the Brazilian *cerrado*. Other minor oils, such as sunflower, do well in hot, dry climates with sometimes poor soils.

Differences among oils as to their suitable growing locations and their labor requirements affect the people who live in those locations and supply the labor. Poverty in developing countries is most extreme and most prevalent in rural areas; and, by and large, the rural poor rely on agriculture for their livelihoods (World Bank, 2007). Prosperous agricultural sectors provide food and cash income to farmers, as well as purchasing power and lower food prices that fuel growth in other sectors of developing countries' economies. Those countries that see growth in oil crops' production are also likely to see reductions in dollar-a-day poverty and malnutrition.

Differences among oils in their land inputs and locations have perhaps the biggest repercussions for the environment. No human activity affects the environment more than agriculture, and, by and large, the location of agriculture determines the location of agriculture's environmental impact[1]. Oil palms thrive in the most biodiverse tropical rainforests: The same warm, wet environments that promote natural biomass accumulation and biodiversity contribute to the oil palm's tremendous yields. Yield differences among oil crops are dramatic, with oil palm yielding seven times as much oil, on a global per hectare basis, as soybean oil[2] (FAO, 2011b). Non-land inputs also differ. Oil palm requires more labor, less fertilizer, and fewer pesticides, on average, than soybean or rapeseed. Given oil palm's tropical suitability, developing new oil palm plantations almost inevitably leads to tropical forest loss.

Given that the environmental crises associated with oil palm are directly related to its production: land appropriation, carbon emissions from peat soils that are drained to grow oil palm, biodiversity loss – studying supply interventions seems like the

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[1] Hypoxia in the Gulf of Mexico, pesticide drift, nitrogen deposition, and contributions to greenhouse gas emissions are notable exceptions.
[2] Soybean meal is a co-product of soybean oil, contributing to soybean 'yield.'

obvious research approach. Scholars and policy makers need to know which actors are engaged in production, where, and how, if they are to encourage more sustainable production systems.

But the demand side of vegetable oils markets matters equally for sustainability, as demand patterns affect the incentives facing producers. In the context of palm oil, the Roundtable on Sustainable Palm Oil -- a convening of market players whose goal is to lessen palm oil's environmental impact -- importantly includes some European buyers as well as Indonesian and Malaysian producers. Insights into demand markets can help to identify the scope of the threats from land conversion and the most promising means of intervention. A major review of the economics of tropical deforestation stated: "Ultimately, unrelenting growth in demand… is the main underlying driver (of deforestation)" (Stevenson, Byerlee, Villoria, Kelley, & Maredia, 2011) p. 18. Which begs the question, "what drives demand?"

The following chapters dissect the demand-side factors that have contributed to a vegetable oils revolution in which palm oil plays the leading role. What are the causes of an extraordinary increase in palm oil consumption over the past twenty-five years? What is the role of population and income growth, the livestock industry, co-products, and biofuels?

Following a background chapter that outlines the extraordinary environmental changes brought about by global vegetable oils production, chapter 3 presents a case study of Indonesia, which today is the world's largest palm oil producing country and has the highest level of per capita palm oil consumption of any country. In Indonesia, higher palm oil consumption is the result not just of population and income growth but also of policies that promoted an extraordinary substitution away from an alternative cooking oil.

Chapter 4 compares Indonesia to its two largest export markets, India and China. Indonesia's experience, it turns out, is not representative of Asia. Different political and economic factors, from livestock consumption to trade policy, contribute to different vegetable oil demand patterns in each of these three markets.

Chapter 5 examines a source of vegetable oil demand that is presently small but potentially enormous. Biodiesel from palm and other oils is the target of much legislation, particularly in the US and Europe, but also, increasingly, in developing countries seeking to save money on fuel imports and/or to boost their domestic agricultural sectors. The chapter asks what effect biodiesel has had on vegetable oil demand and considers how an oil-price shock might play out in vegetable oils markets.

Overall, the thesis paints a strong demand picture for palm oil. Given the highly substitutable nature of vegetable oils markets, small changes in relative prices can have exaggerated effects on palm oil demand. Palm oil's low production costs – tropical producing countries tend to have cheap labor and few restrictions on land acquisition – have impacts on demand that go well beyond the demand growth one would expect to see from population and income, alone. The demand analysis in this thesis suggests that low production costs are particularly important in markets for vegetable oils, where relatively easy substitution creates price-sensitive demand – demand that is highly elastic.

The structure of palm oil demand has implications for policy. Interventions that lead to higher yields are likely to cause more land conversion for oil palm if producers face an elastic demand schedule. Paradoxically, in a future with biodiesel mandates, or where palm oil has crowded out other vegetable oils, palm oil demand would become much more inelastic and yield improvements would be land-saving. In addition, palm oil's naturally high yields would reduce the total amount of land area dedicated to agriculture. But not in Indonesia. In Indonesia, the vegetable oils revolution will continue turning forests into riches.

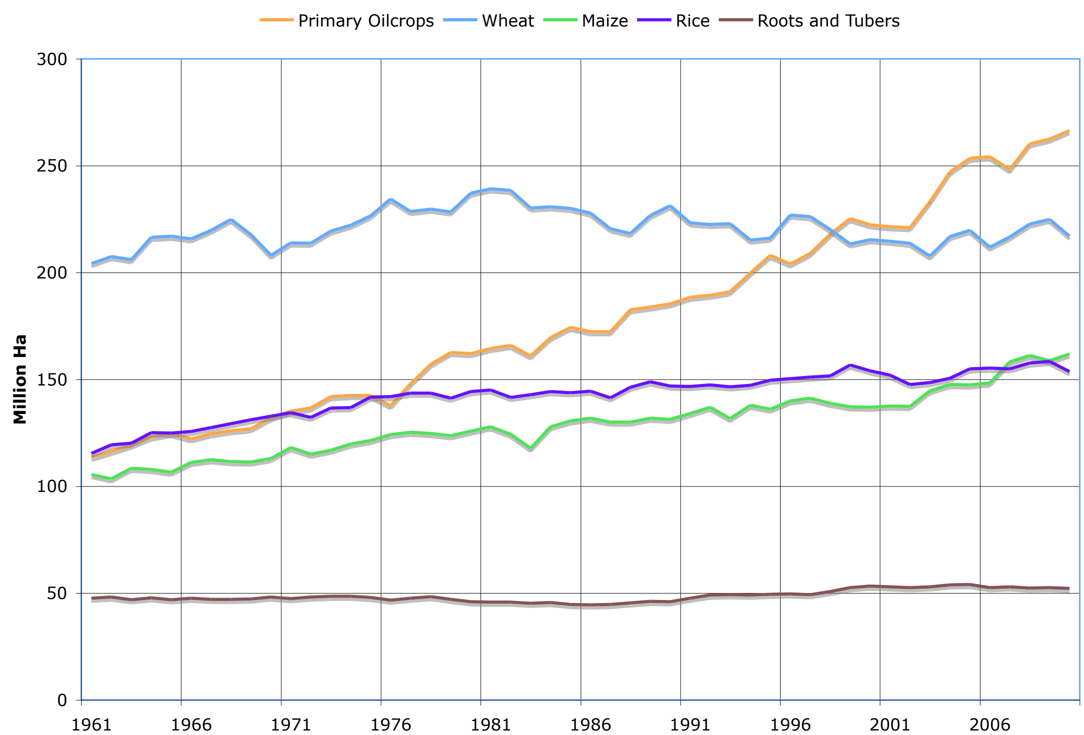

Figure 1-1. Global Area for selected crops (million ha).
The area planted to oil-crops (orange line) has doubled since 1970. Source: (FAO, 2011a)

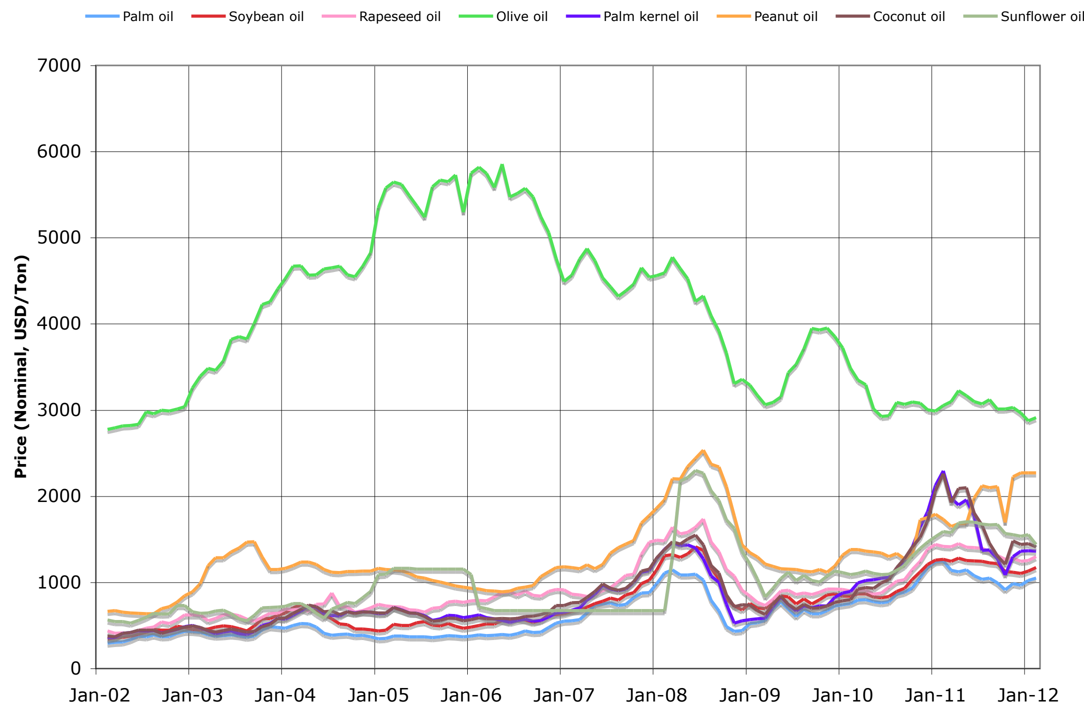

Figure 1-2. Nominal vegetable oils prices over ten years.
With the exception of olive oil (green line), vegetable oils trade within a narrow price band. Source: World Bank, IMF.

Chapter 2 The 1970 - 2010 vegetable oils revolution

Changes in global diets have had dramatic effects on world agricultural systems and the environment. Simultaneously, changes in agricultural technology and practices have, in turn, affected global diets. Livestock and meat consumption is one widely acknowledged realm where dietary changes and production technologies have transformed the environment (Naylor et al., 2005a; Naylor et al., 2005b; Steinfeld et al., 2006). But there is another large sector of the world food economy where changes are also having vast environmental consequences, and that is the market for edible oils.

Over the past few decades, the world's two most common edible oil crops, palm and soy, have expanded faster than any other major food crop in terms of quantity produced, area harvested, and value (see figure 2-1). Oil palm harvested area has increased by over three hundred percent and soybean area has increased by over two hundred percent, while maize, rice, and wheat areas have increased by only forty, nineteen, and eight percent, respectively, since 1970 (FAO, 2011b). Global production, in 2010, was 211 million metric tons of oil palm fruit[3], 262 million tons of soybeans[4], 844 million tons of maize, 672 million tons of rice, and 651 million tons of wheat (FAOSTAT 2012).

[3] Each ton of oil palm fruit produces approximately 0.2 tons of palm oil and 0.03 tons of palm kernel oil.
[4] Each ton of soybeans, when crushed, produces 0.8 tons of soybean meal and 0.2 tons of soybean oil.

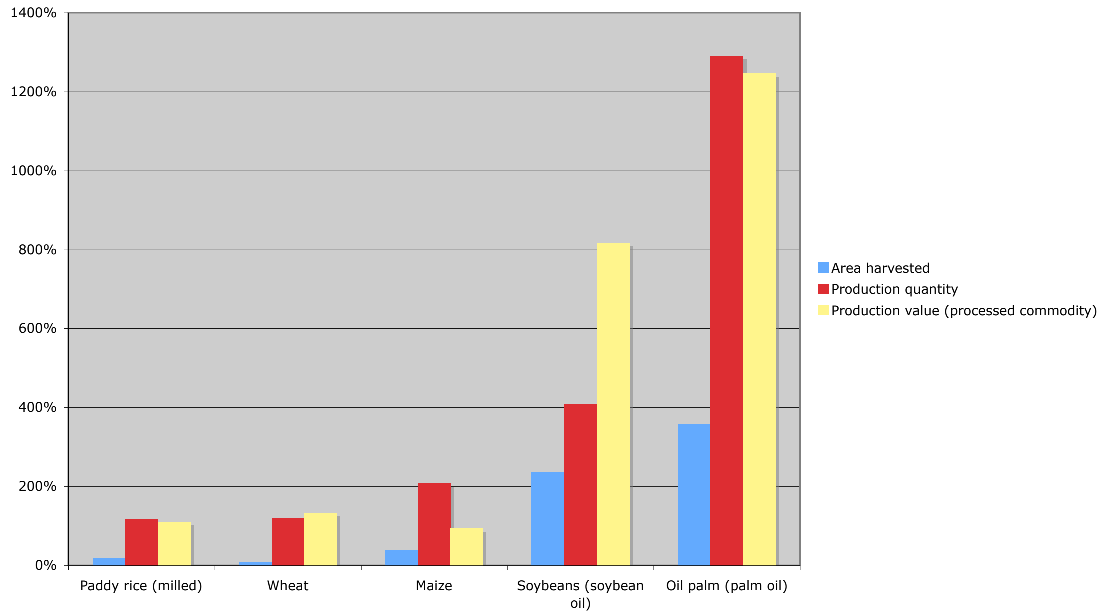

Figure 2-1. Percent change in harvested area, production, and value of major food crops, 1970-2010.
Changes in production value refer to the processed commodity.
Sources: FAOSTAT, World Bank

Global oil crop production is expanding in response to three types of demand: demand for food, demand for industrial purposes, and demand for biofuels. Of these three demand types, food demand is presently the most important. For palm oil and soybean oil, the fraction of production going to food is 72 percent and 82 percent, respectively (see table 2-2). As populations and incomes are growing, globally, human diets are becoming richer in fats and vegetable oils.

A key attribute of the global vegetable oils revolution that affects both demand and supply is the convergence of diets and production systems towards a smaller number of dominant oils. Vegetable oil can be extracted from a wide array of plant species, including fruits (palm oil, olive oil) legumes (soybean oil, peanut oil) and seeds (rapeseed oil, sunflower oil). The oils that are extracted from these different sources all have different fatty acid profiles that produce slightly different tastes, nutritional properties, and cooking properties (see table 2-1).

Palm oil is notable for its high saturation level. Some nutritionists worry that palm oil could increase the risk of cardiovascular disease in developing countries, since lab studies have shown that saturated oils such as palm oil raise total cholesterol and low-density lipoprotein (LDL) plasma concentrations relative to more unsaturated oils (Chen, Seligman, Farquhar, & Goldhaber-Fiebert, 2011; Fuster & Kelly, 2010). Many national and international organizations, including the World Health Organization, recommend reducing saturated fat intake to control the risk of cardiovascular disease (World Health Organization & Food and Agriculture Organization of the United Nations, 2003). In developed countries, palm oil has sometimes been substituted for hydrogenated oils in an effort to eliminate trans-fats; however this strategy may not be effective at improving health, since both palm oil and trans-fats have the same effect of increasing LDL (Chen et al., 2011). Despite its saturation level, palm oil can be an important, low-cost source of calories in poor countries. Additionally, in its unrefined state, palm oil contains carotene and vitamin E that can confer some health benefits.

For all their differences, vegetable oils substitute well for one-another. This is especially true considering the range of processing techniques (hydrogenation, fractionation) that can be used to further modify the properties of vegetable oils, post extraction.

Substitution has by and large been away from diverse oils such as coconut, cottonseed, sunflower, and peanut, towards two major oils – palm and soybean (see figure 2-2). Palm oil's share of the global vegetable oils market rose from just 15 percent in 1985 to 31 percent today, making palm oil the world's most commonly consumed vegetable oil. Soybean oil's share of the world vegetable oil market has remained high since 1985, at close to 30 percent.

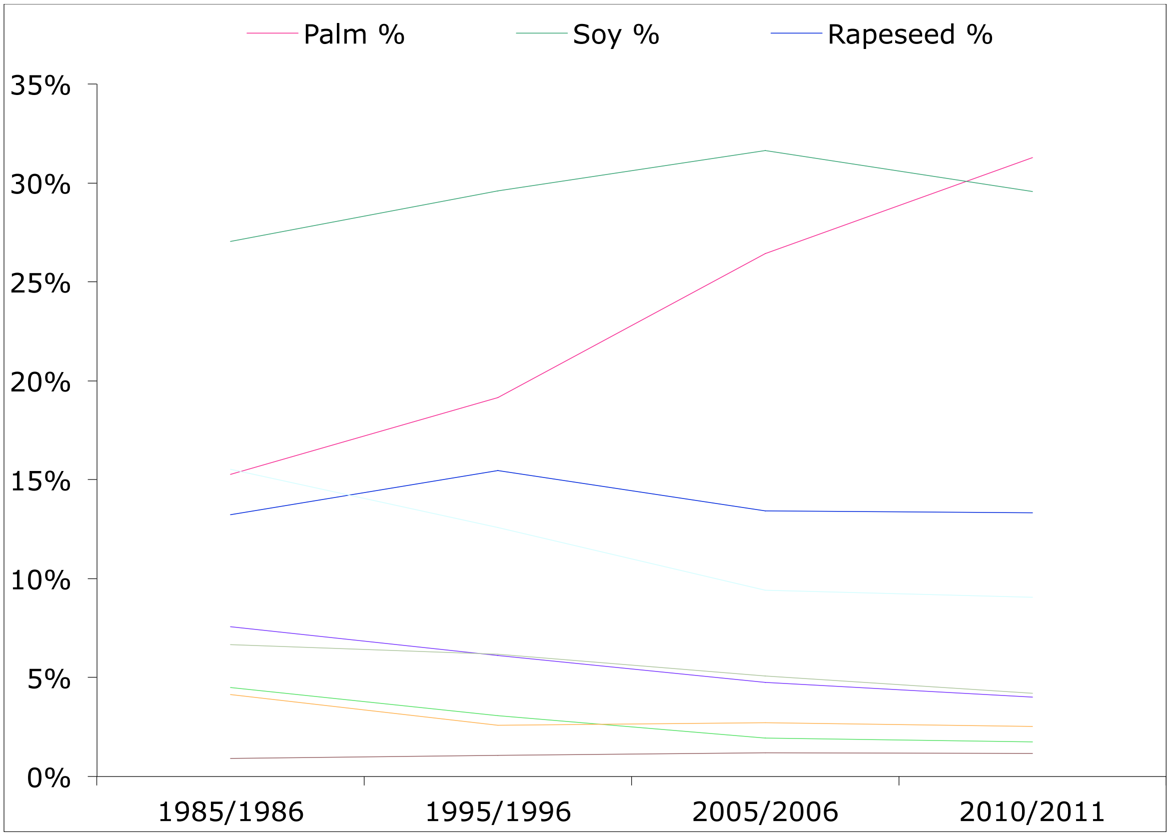

Figure 2-2 Changing composition of global vegetable oils consumption, 1965 – 2010.
Source: USDA 2012

Table 2-1 Consumable properties of selected vegetable oils

	Palm oil	Soybean oil	Rapeseed oil	Sunflower oil	Palm kernel oil	Peanut oil	Coconut oil	Olive oil
Saturated %	52% (high)	15%	7% (low)	11%	80% (high)	18%	92% (high)	14%
Smoke point	230 °C	241 °C	242 °C	246 °C	232 °C	231 °C	177 °C	225 °C
Nutritional properties[5]	Carotene, tocopherols, sterols in unrefined oil	Gamma-tocopherol (anti-oxidant)	High in omega-3 fatty acids	High in omega-6 fatty acids	Highly saturated	High monosaturate content, aflatoxin risk	Highly saturated	High in monounsaturates vitamin E, phenolics
Common end-uses	Cooking oil, margarine, cosmetics	Cooking oil, margarine, shortening	Frying, baking, biodiesel	Cooking oil, margarine, shortening	Processed foods, soap	Frying, cooking oil, margarine	Baked goods, processed sweets, shortening	Cooking, salad oil, margarine
Global market share, 2010	34%	29%	16%	9%	4%	4%	3%	2%
Food use (%)[6]	72%	82%	69%	94%	27%	100%	53%	98%
World price, USD/ton, 2000-2010 avg. (Std. Dev)	624 (271)	751 (289)	914 (316)	1018 (431)	841 (419)	1332 (452)	863 (429)	4072 (950)
Top producing countries, 2010[7]	Indonesia, Malaysia, Thailand	USA, China[8], Brazil	China, Germany, India	Ukraine, Russia, Argentina	Indonesia, Malaysia, Nigeria	China, India, Nigeria	Philippines, Indonesia, India	Spain, Italy, Greece
Top consuming countries, 2010	India, Indonesia, China	China, United States, Brazil	Europe, China, India	Europe, Russia, India	Malaysia, Indonesia, Europe	China, India, Nigeria	Philippines, Europe, United States	Europe, United States, Turkey

5 (Foster, Williamson, & Lunn, 2009)
6 Based on USDA production, supply, and distribution tables, 2012
7 Based on 2008-2010 average production, FAOSTAT

From an environmental perspective, the growth of oil palm and soybean production has transformed millions of hectares of the earth's surface, competing for land area with the world's largest remaining tropical rainforests in Brazil and Indonesia. Oil palm and soybean are notable for their land-intensiveness of new production. Whereas, over the past 40 years, wheat areas shrank and maize and rice areas grew only slightly (while yields improved), soybean and palm oil areas ballooned, accounting for the majority of production increases for those two oil crops (see table 2-2). Area expansion accounted for 60 percent of global oil palm production growth and 68 percent of global soybean production growth between 1970 and 2009. In Asia between 1995 and 2009, area's share of palm oil production growth was 92 percent (FAO, 2011a).

Table 2-2 Percent production growth from area expansion, 1970-2009, for major food crops (global average).
Levels are shown below for reference. Source: Author's calculations based on FAOSTAT

Crop	Annual production growth rate	Area growth rate	Yield growth rate	% Production growth from area expansion
Oil palm fruit	7.06%	4.25%	2.81%	60.20%
Soybeans	4.03%	2.74%	1.30%	67.99%
Maize	2.46%	0.71%	1.75%	28.86%
Wheat	1.66%	-0.10%	1.76%	-6.02%
Rice	2.01%	0.36%	1.65%	17.91%
	2009 Production (million tons)	**2009 Area (million Ha)**	**2009 Yield (000 Hg/Ha)**	
Oil palm fruit	207.3	14.7	140.7	
Soybeans	223.2	99.5	22.4	
Maize	818.8	158.6	51.6	
Wheat	685.6	225.6	30.4	
Rice	685.2	158.3	43.3	

Given the threats that agricultural expansion poses for the environment, the land-intensiveness of production increases for oil palm and soybean is alarming. Globally, agriculture is one of the biggest threats to forests and biodiversity, particularly in the tropics (Cassman & Wood, 2005; Clay, 2004; Donald, 2004; Gibbs et al., 2010). Geist and Lambin (2002), in a meta-analysis of factors causing tropical deforestation, write that 'agriculture is, by far, the leading land-use change associated with nearly all deforestation cases (96%).' The meta-analysis revealed that agriculture is particularly relevant for Asian deforestation: wood extraction was a factor in 89 percent of deforestation cases, whereas agriculture was a factor in 100 percent of reviewed deforestation cases in Asia (Geist & Lambin, 2002).

Tropical forests, which harbor seventy percent of the world's plant and animal species, are under siege from soybean and palm production. In Brazil, soybean planting in the *cerrado* (scrub savanna) and cleared areas of Amazonia has expanded to meet rising feed demand in China and other emerging economies, at high cost to biodiversity (Fearnside, 2001; Nepstad, Stickler, & Almeida, 2006). Up until the early 1990s, soybean production was trivial in the Amazon (Nepstad et al., 2006). Now, however, Brazil is the world's second largest soybean producer, after the United States, thanks to a long growing season, agronomic advances that make nutrient-poor tropical soils suitable for growing soybeans, and large investments in roads and infrastructure. In Mato Grosso, Brazil's largest soybean producing state, new cropland was responsible for up to 23 percent of annual deforestation between 2001 and 2004, with clearing sizes that were twice as large as clearings for pasture (Morton et al., 2006). Since 2006, soybean infrastructure investments have been coupled with stricter land-use legislation, monitoring, and enforcement that are measurably reducing rates of deforestation, even as production is increasing (Macedo et al., 2012).

Palm oil, the world's most common vegetable oil, poses an equal if not a greater threat to forest loss and biodiversity than does soybean planting (Fitzherbert et al., 2008; Hartemink, 2005). Indonesia possesses the largest remaining expanse of tropical forests in Asia, and Indonesia is also the world's largest palm oil producer. Between 1990 and 2010, Indonesia lost 20.3 percent of its forest cover, or around 24,113,000 ha, at an average loss rate of 1.02 percent per year (Mongabay, 2012). Deforestation in

Kalimantan, Indonesia averaged 2.9 percent per year between 1989 and 2008, of which, by 2007- 2008, 23 percent was directly attributable to oil palm expansion (Carlson et al., 2012; Curran et al., 2004).

The aggregate forest loss associated with new palm oil plantations in Indonesia is debated. Koh and Wilcove (2008) find that between 1990 and 2005, 1.7 million hectares of Indonesian forest were converted to oil palm plantations, an area equal to 65 percent of new oil palm areas in Indonesia (Koh & Wilcove, 2008). Gibbs et al. (2010) measure that roughly half of new agricultural plantations in Southeast Asia came from cropland in the 1980s and that nearly 70% of new plantations came from cropland in the 1990s. The remainder of the land for new plantations came from forests (Gibbs et al., 2010). The share of new palm oil plantations coming from forests seems to have been declining and may continue to fall in major oil-palm producing regions, such as Sumatra and Kalimantan, as these regions have less forest left to convert, and as policy and international observance becomes more rigorous. In regions with dwindling forest cover, expanding oil palm plantations may shift to peat lands or present trade-offs with fallow areas, rubber gardens or upland rice (Carlson et al., 2012). Elsewhere in Indonesia, and elsewhere along the equator, palm oil expansion will likely continue to be associated with high rates of deforestation.

As the vegetable oils revolution is shrinking tropical forests, changing crop production patterns are helping to grow some tropical economies. Between 1970 and 2010, the value of soybean production increased by 800 percent and the value of palm oil production increased by 1200 percent (see figure 2-1) (FAO, 2011c; World Bank, 2011). Given that agriculture is the primary source of employment and income generation for the world's poor, evolving crop production patterns in the tropics are critical to economic development (World Bank, 2007). Agricultural revenues from oil crop exports are accruing to countries, such as Brazil and Indonesia, where rural poverty alleviation is a top priority. The equity impacts of oil palm, however, remain unclear. Oil palm production is capital intensive, so most investors are among the wealthy.

In Indonesia, the oil palm industry provides valuable income, employment, tax revenues, and foreign exchange. Oil palm plantations are profitable: IDR 5.2 million (approximately USD $577[9]) per hectare, according one Indonesian government survey, including fixed costs, capital costs, and taxes (BPS 2003). Those profits would be sufficient to raise Sumatran farmers over the local poverty line if farmers had approximately 1.5 hectares to cultivate (Susila, 2004; World Bank & IFC, 2011)[10]. Reported national poverty headcount rates in Indonesia seem to bear this out: A district-level regression of palm oil areas on poverty headcounts for Indonesia found that, between 2005 and 2008, a one percent increase in hectares of palm oil production contributed to a reduction of between 0.15 to 0.25 percentage points of those in poverty, on average (Susila, 2004; World Bank & IFC, 2011). Differences between districts might be explained by different land ownership structures and different revenue sharing models on corporate plantations, in addition to the presence of independent smallholders. Indonesia's oil palm industry employs some 2-3 million Indonesians, in total, out of a total population of 240 million and a labor force of 117 million (World Bank & IFC, 2011). It is thus clear where and how the tension between environmental protection and economic growth arise in the vegetable oil sector.

The following chapters investigate the 'what' and 'why' of global vegetable oil demand, and palm oil demand in particular, to uncover historical patterns and future trends that might shape patterns of agricultural expansion and development, particularly in the tropics. Indonesia, the world's largest palm oil producer and the world's largest palm oil consumer, is the subject of the next chapter.

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[9] Unless otherwise noted, all prices are in 2010 US dollars.
[10] Local poverty lines in the two study districts were IDR 5 million and IDR 7.1 million.

Chapter 3 The role of markets, technology and policy in generating demand for palm oil in Indonesia

Palm oil's emergence as the world's dominant vegetable oil has been striking. The industry grew quickly, from a small global base of 6 million tons in 1985 to 36 million tons of production today, more production than any other vegetable oil (USDA, 2011b). Palm oil's economic benefits for producing countries such as Indonesia have been huge: for the last decade, palm oil has been Indonesia's largest agricultural export and has employed, in production and processing, some 2-3 million Indonesians, or about two percent of Indonesia's labor force (World Bank & IFC, 2011; World Growth, 2011). Palm oil's environmental costs, however, have also been significant (Butler, Pin Koh, & Ghaoul, 2009; Koh & Wilcove, 2008; Wilcove & Koh, 2010). While most major food crops, including soybeans, have achieved higher production through intensification, Asian palm oil production growth since 1995 has relied almost exclusively (92%) on area expansion to meet demand (FAO, 2011b). Indonesian palm oil production thus threatens the world's second largest remaining tropical rainforest.

What is causing this phenomenal growth in palm oil production? Is palm oil development in Indonesia likely to continue at a fast pace? There are good economic reasons why most of the world's cooking oil should come from oil palm. Oil palm plantations produce nine times as much vegetable oil on a per hectare basis than do soybean fields, and land and labor inputs in the tropics, where oil palms thrive, are generally cheaper in market terms than in Europe or North America. Oil palm trees also require fewer chemical inputs relative to soy and rapeseed.

Demand-side factors enhance these supply advantages. Palm oil's steadily growing importance in world vegetable oils markets is largely a function of Asian economic development and associated growth in demand. The first part of this chapter considers the sources of growth for palm oil demand in the world's leading palm oil consuming country, Indonesia, by approaching the task with a standard demand equation – an approach that produces very inadequate answers. The second part of the chapter examines the key role of the Indonesian government in altering cooking oil preferences. Supplementing the economic model with an understanding of development projects and programs that promoted palm oil is necessary in order to fully explain Indonesian consumption dynamics.

A partial equilibrium approach to demand analysis: an exercise in hind-casting

A first step in analyzing Indonesian palm oil consumption is to use a partial-equilibrium demand framework. Economic development boosts Indonesian palm oil consumption by shifting the basic structural determinants of demand. In the model:

$$(1) \qquad q^d_{CPO,Food} = \varepsilon_{CPO,Food} p_{CPO} + \eta_{CPO,Food} y + \Delta^{Pop} + \Delta^{Urban} + \sum_i \varepsilon_{i,food} p_i + e$$

The right hand side variables are: the price elasticity of palm oil demand for food ($\varepsilon_{CPO,Food}$) multiplied by the percent change in palm oil price (p_{CPO}); the income elasticity of palm oil demand for food ($\eta_{CPO,Food}$) multiplied by the percent change in real per capita income (y); shifts due to population (Δ^{Pop}) and urbanization (Δ^{Urban}); the sum of cross price elasticities of demand for other vegetable oils multiplied by the percent changes in those vegetable oil prices ($\sum_i \varepsilon_{i,food} p_i$); and an error term ($e$).

Each of the independent variables, with the exception of prices, carry positive coefficients and have increased in Indonesia over the past twenty-five years, following trends in the rest of Asia (see table 3-1). Indonesia's population grew by forty-two percent between 1985 and 2010; per capita incomes more than doubled in real terms; and the urban population grew at 7.5 percent per annum – faster than China's (6.3%) or India's (4.3%). While Indonesia is a typical example of population and income growth trends across Asia, Indonesia is an extreme example of palm oil consumption growth. Total Indonesian palm oil consumption has risen a hundred-fold in the past twenty-five years, from five hundred thousand to five million tons. In per capita terms, no other country has experienced similarly large increases in palm oil consumption.

Table 3-1 Data on demand and its determinants.
Data sources: (Global Financial Data, 2011; USDA, 2011b; World Bank, 2010)

	1985	2010	Change (%)	Compound annual growth
Palm oil consumption (1000 Tonnes)	501	4,750	848%	9.4%
Population (millions)	162	230	42%	1.4%
Palm oil consumption per capita (kg)	3.09	20.66	569%	7.9%
Real GDP per capita (yr 2000 USD)	476	1124	136%	3.5%
Urbanization percent	26.1%	52.6%	101%	2.8%
Palm oil price trend, real (USD/Tonne)	797.17	486.12	-39%	-2.0%
Fraction of vegetable oil from palm	37.81%	94.19%	149%	3.7%

Population effects

Population growth accounts for between five and thirty-three percent of Indonesia's growth in palm oil consumption between 1985 and 2010. Total consumption growth can be expressed in terms of population growth and per capital consumption growth as follows:

$$T_2 - T_1 = P_2C_2 - P_1C_1 = C_1(P_2 - P_1) + P_1(C_2 - C_1) + (P_2 - P_1)(C_2 - C_1)$$

Where T is total consumption; P is population; C is per capita consumption; and the subscripts 1 and 2 denote time periods 1985 and 2010, respectively. Thus, the difference in total consumption between the periods 1985 and 2010 is the sum of: a term that depends only on population growth, ($P_2 - P_1$); a term that depends only on per capita consumption growth (C_2-C_1); and a term that depends on the interaction between population growth and consumption growth. The shaded areas in figure 3-1 show the magnitudes of these three terms. The smallest rectangle, accounting for five percent of total consumption growth, represents consumption growth that is uniquely due to population growth, holding per capita consumption constant at the 1985 level.

The next largest rectangle, accounting for twenty-eight percent of total consumption growth, represents the interaction of income growth and higher per capita consumption. The largest rectangle, accounting for sixty-seven percent of total consumption growth, represents consumption growth that is separate from population growth. At Indonesia's 1985 population level, total consumption at today's consumption rate of 21 kg/capita would be 290 million tonnes, rather than the actual figure of 420 million tonnes. Population growth and per capita consumption growth are both important factors, but per capita growth has been the bigger factor and is also more uncertain when it comes to future trends.

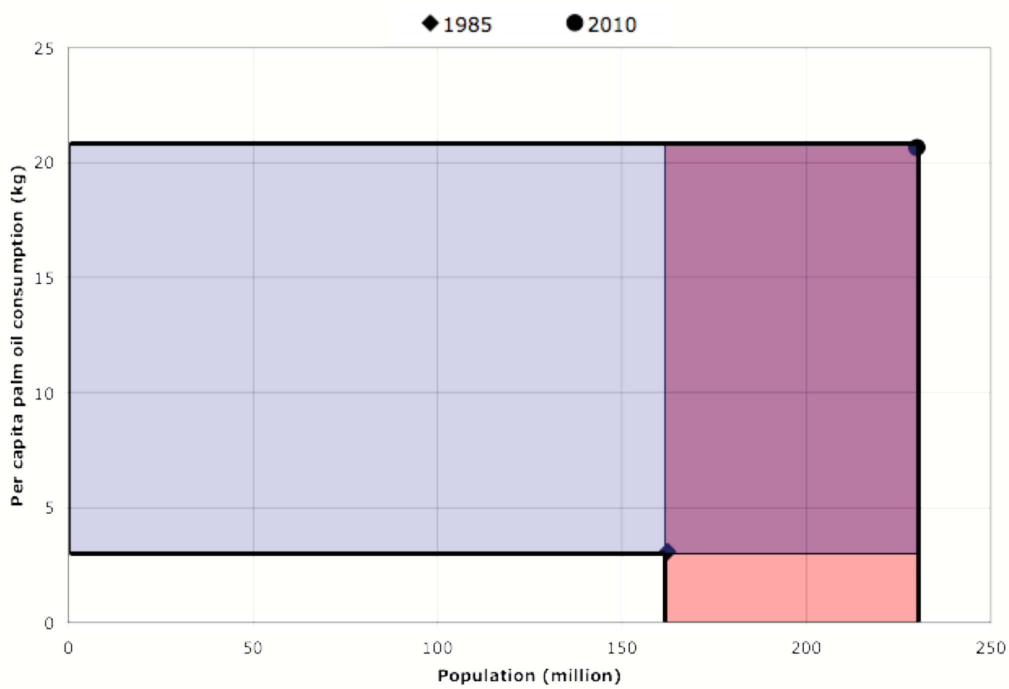

Figure 3-1. Population's contribution to higher Indonesian palm oil consumption. The colored areas represent Indonesia's total increase in palm oil consumption between 1985 and 2010. Rectangles show the contribution of population growth (red); population growth * per capita consumption growth (purple) and consumption growth (blue). Data sources: (USDA, 2011b; World Bank, 2010)

Income effects

The first explanation for a surge in per capita Indonesian palm oil consumption is income growth: as incomes rise, Indonesians have more money to spend on food. Income elasticities of consumption are particularly high when people start out poor because the poor spend a larger fraction of their incomes on food (Timmer, Falcon, & Pearson, 1983a; USDA Economic Research Service, 2010). In 1992, the World Bank estimated Indonesian vegetable oil income elasticities within a range of 0.6 – 0.8 (World Bank, Agricultural Operations Division, 1992). The least-squares estimate of Indonesia's income elasticity of palm oil consumption for 2007, based on cross-sectional national household survey data, is 0.4 (Badan Pusat Statistik, 2009) (see figure 3-2). This coefficient suggests that Indonesia's income elasticity of consumption for vegetable oils is falling over time, as expected.[11]

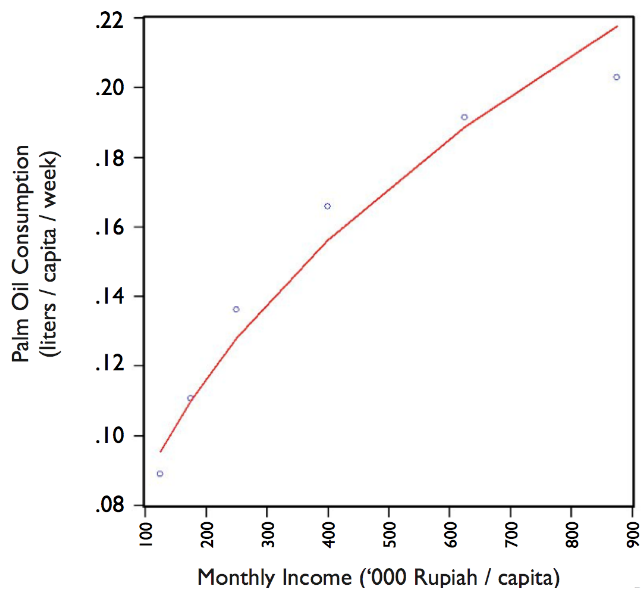

Figure 3-2. Engel curve, Indonesia.
The blue dots represent average weekly palm oil consumption at the midpoint of each of six income classes. Data were omitted for the highest income class because its midpoint could not be computed. The red open-ended line represents the least squares estimate of the log-linear demand model ($\ln C = a + \beta \ln Y$), where $\beta = 0.4$. Data source: (Indonesian Palm Oil Board, 2008)

[11] By contrast, the income elasticity of demand for Indonesia's main staple, rice is approximately 0.1, and may soon be negative (Timmer, Block, & Dawe, 2010).

Income growth explains some, but far from all, of Indonesia's higher per capita palm oil consumption (see figure 3-3). Despite strong economic performance – Indonesian real incomes have more than doubled in the past 25 years, from USD 476 per capita to USD 1124[12] (World Bank, 2010) -- explaining all of Indonesia's higher per capita palm oil consumption based on higher incomes alone would require an extraordinary income elasticity of 4.2. A high, but more reasonable income elasticity estimate of 0.8 still only explains 19 percent of Indonesia's actual increase in per capita palm oil consumption for food (see table 3-2). An income elasticity of 0.4 applied across Indonesia explains a jump in palm oil consumption of 1.7 kg per capita, or about ten percent of the observed per capita consumption growth.

Table 3-2 Income elasticities and higher per capita palm oil consumption, 1985 – 2010.

Source: Author's calculations

Income elasticity assumption	Comments	Predicted increase in Indonesian per capita palm oil consumption, 1985 – 2010 (kg)	Percent of actual increase
0.4	Derived from 2002 SUSENAS[13]	1.7	10
0.8	High estimate	3.4	19
4.2	Max required to uniquely explain observed increase	17.6	100

In the future, as Indonesian incomes continue to rise, there is perhaps a fixed amount of additional palm oil consumption that higher incomes will generate. Patterns of palm oil consumption by income class reveal some 'topping out' at the highest income levels, particularly among rural consumers (see table 3-3). However, an important caveat is that the SUSENAS surveys do not account for palm oil consumed outside the home that is incorporated into prepared foods as part of the overall palm oil consumption figures. Urban consumers show less evidence in the SUSENAS data of reaching a maximum level of consumption. In 2007, the median rural consumer in

[12] World Bank Indonesian GDP deflator, Not PPP adjusted
[13] Indonesia's national socioeconomic survey

Indonesia used 0.14 L/week of cooking oil, 67% of the maximum rural value of 0.21. Thus, as incomes grow, there is room for expansion towards this ceiling.

Table 3-3 Average weekly consumption, 2007.
Source: (Indonesian Palm Oil Board, 2008)

Expenditure class (IDR/month)	Consumption (L/cap/wk)		
	Urban	Rural	Total
<100,000	0.06	0.06	0.06
100,000-149999	0.09	0.09	0.09
150,000-199,999	0.11	0.11	0.11
200,000-299,999	0.14	0.14	0.14
300,000-499,999	0.16	0.17	0.17
500000-749999	0.19	0.21	0.19
750000-999999	0.20	0.20	0.20
>1000000	0.22	0.21	0.22

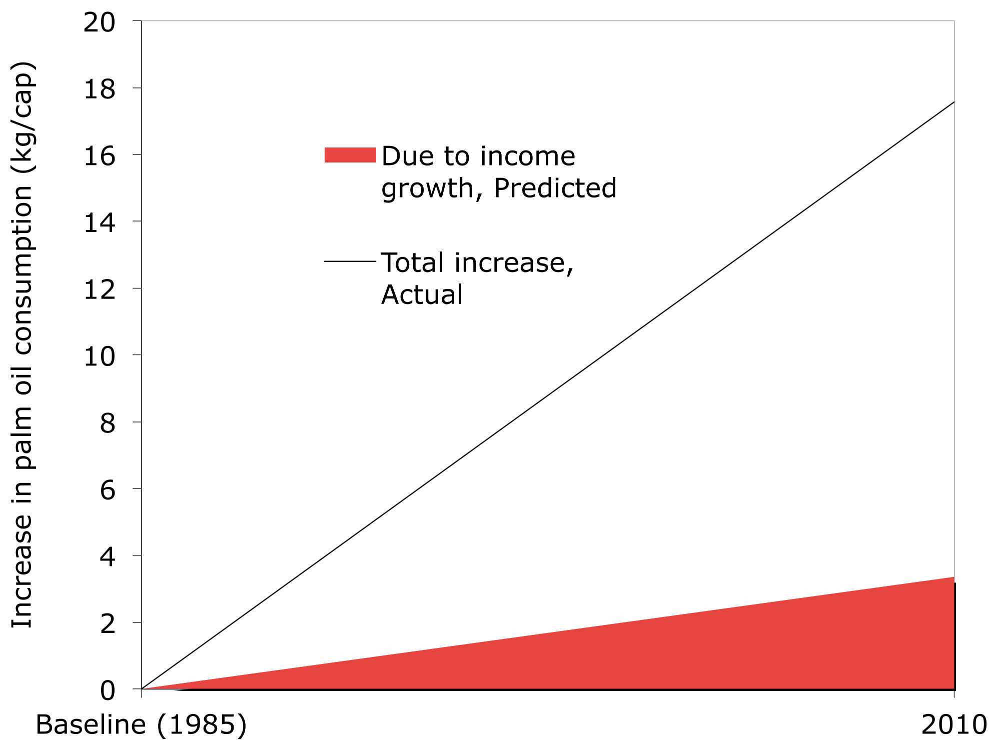

Figure 3-3. Contribution of income growth to higher per capita palm oil consumption in Indonesia (e = 0.8).
Source: Author's calculations based on (USDA, 2011b; World Bank, 2010)

Urbanization effects

Urbanization may also contribute to higher per capita palm oil consumption. Indonesia has urbanized rapidly in the past quarter century, more so than the world average. While China and India grew their urban populations by 6.3 percent per annum and 4.4 percent per annum, respectively, since 1985, Indonesia's urban population grew by 7.5 percent. Urbanization may contribute to diets that are heavier in cooking oil as workers and their families substitute towards fast-food type fried meals[14] that they purchase on the street. This additional palm oil consumption would be captured in the SUSENAS data through the cooking oil purchases that small vendors make. Indonesia's household survey for 2002 shows slightly higher palm oil consumption in urban areas (Indonesian Palm Oil Commission (IOPC), 2004; Indonesian Palm Oil Commission (IOPC), 2006) (Table 3-4). Holding incomes constant, a paired t-test shows urban Indonesians consumed significantly more cooking oil on average than rural Indonesians in the same income bracket ($p = 0.01$). However, the mean difference was only 0.01 kg per person per week or 5 percent of average consumption[15]. In 2007, however, a similar survey reveals no significant difference between rural and urban palm oil consumption, conditional on income. Thus, there is some evidence for convergence in consumption patterns between rural and urban consumers; however, since the SUSENAS surveys do not account for palm oil consumed outside the home that is incorporated into prepared foods as part of the overall palm oil consumption figures, the urban-rural difference in cooking oil consumption is likely larger than the table below suggests.

[14] These street foods include fried rice (*nasi goreng*), fried noodles (*mie goreng*), fried chicken (*ayam goreng*), etc.
[15] Difference for the median income group was 0.03 kg/cap/week; with only nine income classes it is not obvious whether the data are normally distributed.

Table 3-4 Average consumption per capita (L/week) by income class in urban and rural areas.
Source: (Indonesian Palm Oil Board, 2008; Indonesian Palm Oil Commission (IOPC), 2004)

Income class (IDR/month)	**2002**			**2007**		
	Urban	Rural	Total	Urban	Rural	Total
<100,000	0.07	0.06	0.07	0.06	0.06	0.06
100,000-149999	0.09	0.09	0.09	0.09	0.09	0.09
150,000-199,999	0.11	0.10	0.11	0.11	0.11	0.11
200,000-299,999	0.13	0.12	0.12	0.14	0.14	0.14
300,000-499,999	0.15	0.15	0.15	0.16	0.17	0.17
>500,000	0.17	0.14	0.17	0.20	0.21	0.20

Whether the difference in palm oil consumption between urban and rural Indonesians is zero or as large twenty percent, the direct impact of urbanization on palm oil consumption is small. Assuming that urban Indonesians consume twenty percent more palm oil than rural Indonesians implies that as urbanization jumped from 26 to 53 percent in Indonesia between 1985 and 2010, migration accounted for only a 0.24 kg/capita consumption increase on average for the country[16] out of a total increase of 18 kg / capita, holding incomes constant. This small effect is not the 'missing factor' that explains Indonesia's extraordinary growth in palm oil consumption. The error term in equation 1 is still enormous (see figure 3-4).

[16] Analysis assumes migrants consumed the average amount of palm oil in 2010.

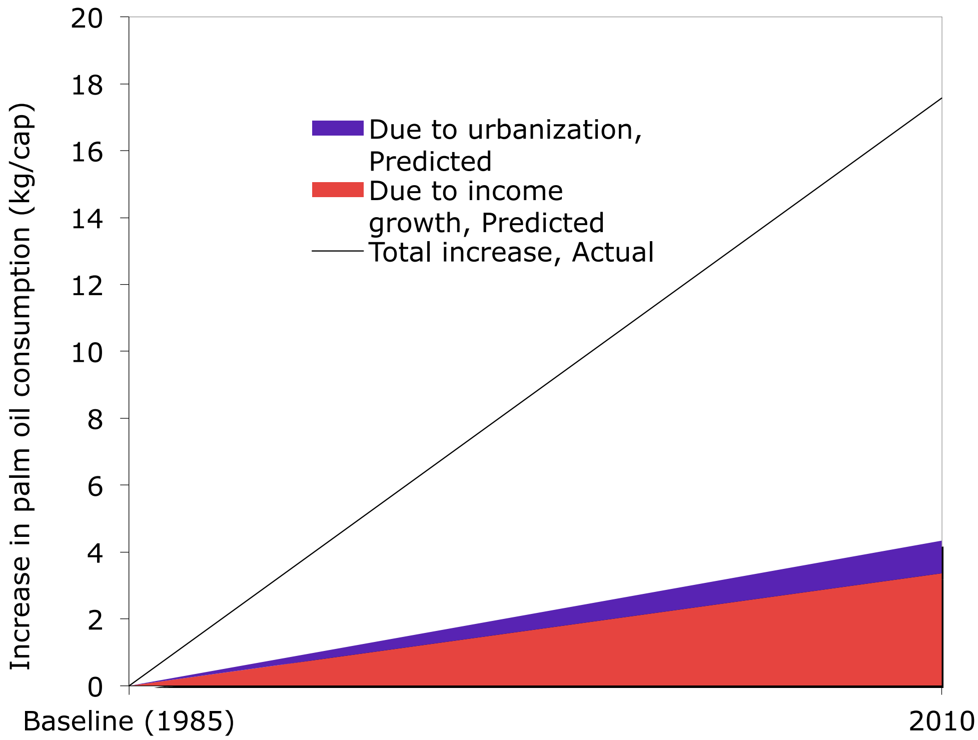

Figure 3-4. Contribution of urbanization to higher per capita palm oil consumption in Indonesia (urban multiplier = 1.2).
Source: Author's calculations based on (USDA, 2011b; World Bank, 2010)

Own-price effects

Combined, demographic factors are only moderately helpful in explaining long run changes in Indonesian palm oil demand. Lower prices are potentially another factor that accounts for higher consumption. As some input costs have fallen and yields have increased, supply curves have shifted out faster than demand curves, causing real palm oil prices to fall (see figure 3-5). International prices have fallen the most steeply, an average of 1.3 percent per annum over the twenty years between 1985 and 2005, or 13 percent in real terms[17] (Global Financial Data, 2011). In Jakarta, the price per bottle of cooking oil fell at an inflation adjusted rate of 0.7 percent per annum between 1985 and 2005, a more moderate decline that reflects government efforts to stabilize cooking oil prices (Badan Pusat Statistik (BPS), 2006). In both cases, a straight-line trend masks tremendous price volatility.

[17] World Bank Indonesian GDP deflator

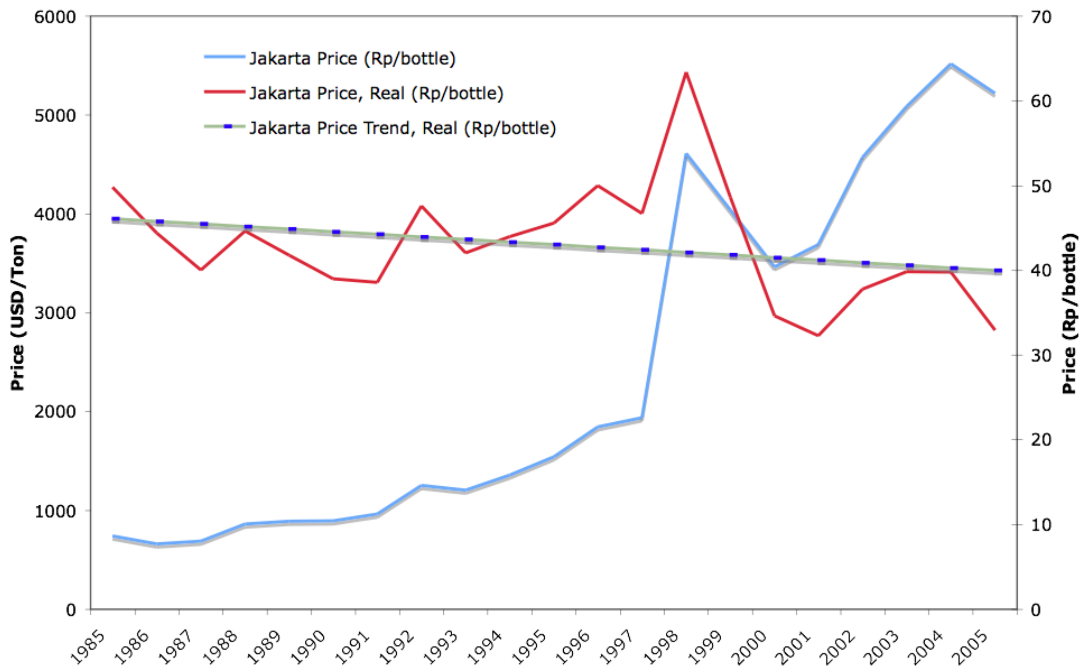

Figure 3-5. Real Jakarta cooking oil price, 1985 - 2005.
In blue is the nominal retail price of cooking oil in Jakarta (BPS 2006 (Badan Pusat Statistik (BPS), 2006)); in red is this same domestic retail price deflated using the World Bank's implicit GDP deflator for Indonesia. The dotted line is a linear approximation of the red line, highlighting the declining trend in real domestic cooking oil prices.

Between 2005 and 2010, international palm oil prices rose 14 percent annually in real terms, from USD[18] 422 per ton in 2005 to USD 798 in 2010 (World Bank, 2012). Indonesian cooking oil prices undoubtedly experienced some fraction of this price increase.

Price elasticities measure how consumers respond to changing prices. Older estimates of vegetable oil's own-price elasticity in Indonesia is -1.3 to -0.26, with poorer consumers and rural consumers responding the most to price changes (Monteverde, 1987). Price elasticities for vegetable oil are probably lower (in absolute value) in Indonesia today than they were in the 1980s because incomes have risen. Poorer and

[18] 2005 dollars

urban consumers spend more of their incomes on cooking oil so a price decline (increase) makes them relatively wealthier (poorer), amplifying the price change's effect[19]. Own-price elasticities for any individual vegetable oil, including palm oil, would be higher than the own-price elasticity for vegetable oil as a category since individual vegetable oils substitute easily with one another. The next section of this paper discusses cross-price elasticities and substitution in more detail.

Regardless of whether the own-price elasticity of demand is approximated as -0.3 or -1.3, falling international prices explain less than ten percent of Indonesia's extraordinary per capita palm oil consumption growth (see figure 3-6). And, in fact, prices have not fallen consistently. A price elasticity of -0.3 explains two percent of the observed increase in per capita consumption and a price elasticity of -1.3 explains nine percent. Using domestic prices rather than international prices for the period 1985 – 2005 generates similar results: the overall increase in Indonesian consumption during this period was less, but the price changes within Indonesia were also more moderate due to government consumption subsidies and trade barriers. Domestic Indonesian cooking oil's downward price trend explains between two and eight percent of per capita palm oil consumption growth during this period. Using actual prices, rather than a smooth trend, gives a slightly higher price effect since 2005 saw a downward price spike. Non-trended local prices combined with a price elasticity of -0.3 explain two percent of consumption growth; those same prices with a price elasticity of -1.3 explain ten percent of consumption growth (see table 3-5).

[19] The Slutsky equation expresses how income effects and budget shares are part of the price elasticity of demand: $\varepsilon_{x,y} = e_{x,y} - \eta_x \alpha_y$, where ($\varepsilon_{x,y}$) is the price elasticity of demand; ($e_{x,y}$) is the change in demand, holding income constant; (η_x) is the income elasticity of demand for commodity x, and (α_y) is how much income has to change to keep utility constant.

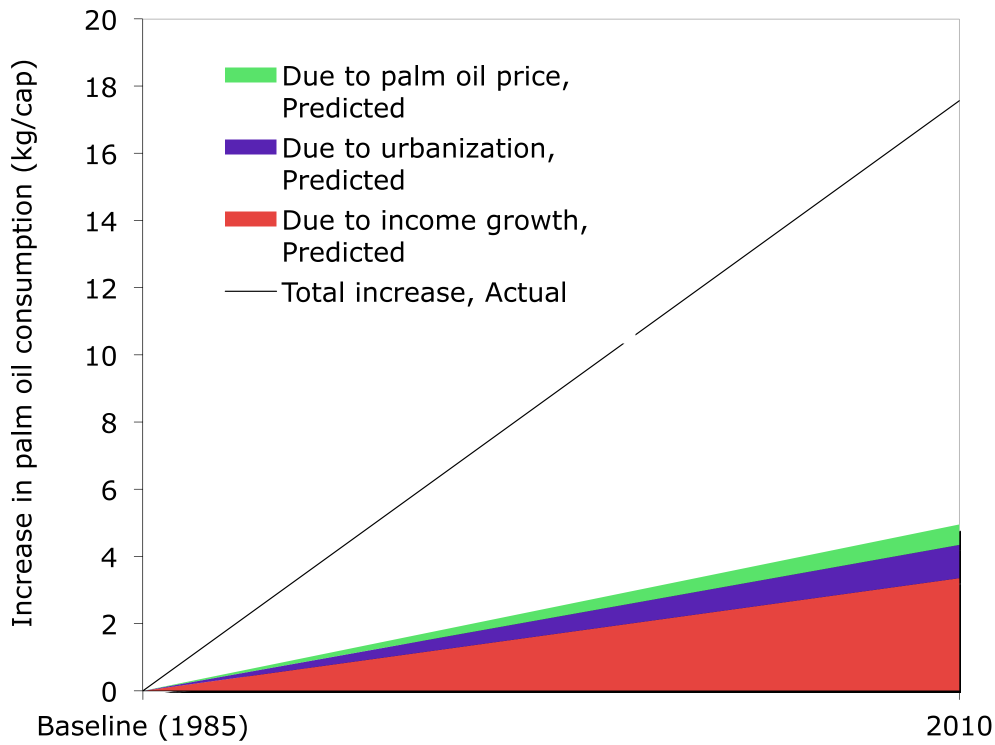

Figure 3-6. Contribution of falling international palm oil prices to higher Indonesian palm oil consumption (e = -0.5).
Source: Author's calculations based on (Global Financial Data, 2011; USDA, 2011b; World Bank, 2010)

Table 3-5 Price elasticities and higher per capita palm oil consumption in Indonesia.
Source: Author's calculations

Assumption	Time period	Prices	Predicted increase	Actual increase	% of actual
-0.3	1985 - 2010	Real int'l trend	0.36	17.6	2%
-1.3	1985 - 2010	Real int'l trend	1.59	17.6	9%
-0.3	1985 - 2005	Real dom. trend	0.26	13.8	2%
-1.3	1985 - 2005	Real dom. trend	1.14	13.8	8%
-0.3	1985 - 2005	Real domestic	0.31	13.8	2%
-1.3	1985 - 2005	Real domestic	1.36	13.8	10%

Substitution effects

The impact of cross-price effects on Indonesian palm oil consumption is difficult to measure, since the domestic price series that are available for 'cooking oil' do not distinguish between oil from coconut and oil from oil palm. Internationally, the relative prices of coconut and palm oil varied considerably during the 'switch-over' period in the 1970s and '80s but did not trend strongly in a single direction, suggesting perhaps a weak role for international markets in the substitution process. In contrast to peanut oil and soybean oil that have become marginally more expensive relative to palm oil over time, coconut oil has become slightly cheaper in international markets relative to palm oil (see table 3-6 and figure 3-7). Thus, changes in international prices do not easily explain Indonesia's vegetable oil substitution process.

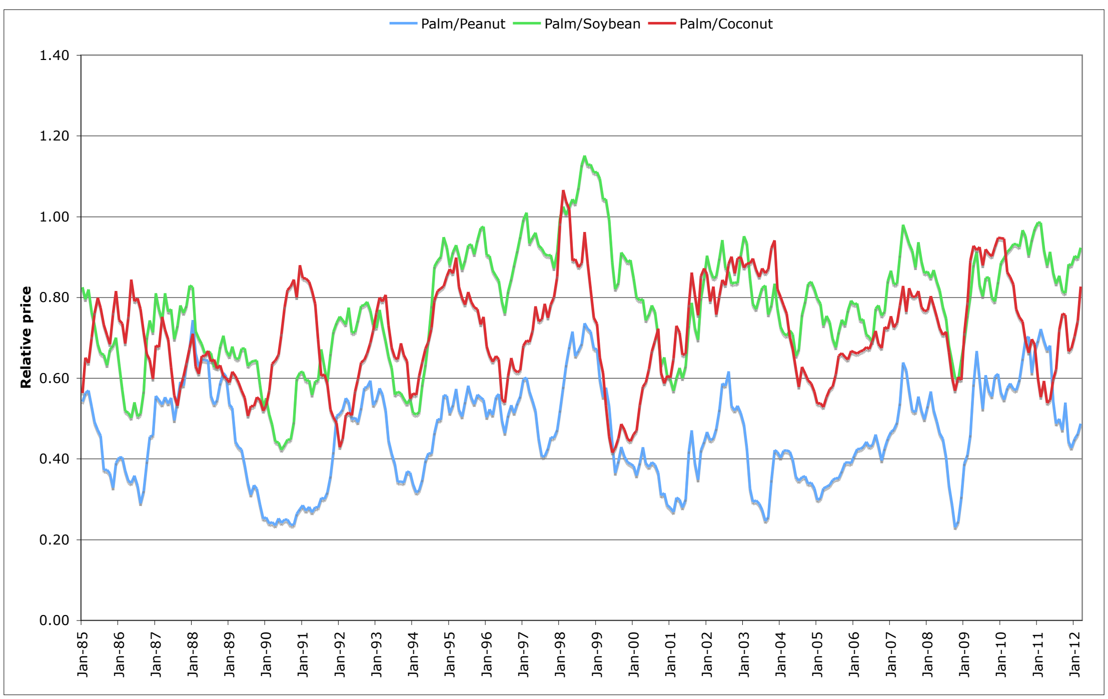

Figure 3-7. International price of palm oil relative to the international price of substitute oils, 1985 - 2012.
Source: IMF, World Bank

Table 3-6 Average annual changes in palm oil's international price relative to other vegetable oils, 1985 – 2010.

Source: (Global Financial Data, 2011)

	Average annual change relative to palm oil
Peanut oil	-0.2%
Soybean oil	-0.2%
Coconut oil	0.1%

Despite weak cross-price effects, at least at the international level, the impact of substitution on palm oil consumption in Indonesia has been enormous. The sizeable fraction of consumption growth that remains to be explained after accounting for higher incomes, urbanization, and falling prices can be explained by substitution between coconut oil and palm oil. As figure 3-8 shows, the story of palm oil's ascendance in Indonesia is equally a story of coconut oil's decline. The correlation coefficient between palm oil's share of Indonesian diets and coconut oil's share is -0.997: as coconut oil consumption has declined, palm oil consumption has increased. In 1965, the vast majority (ninety-eight percent) of Indonesian cooking oil came from coconut with only a tiny amount (two percent) coming from palm oil. In 1985 over half (fifty-four percent) of cooking oil still came from coconut. Today the situation is completely reversed: ninety-four percent of cooking oil comes from palm oil, with only three percent coming from coconut. The reversal in forty years has been dramatic (see figure 3-8).

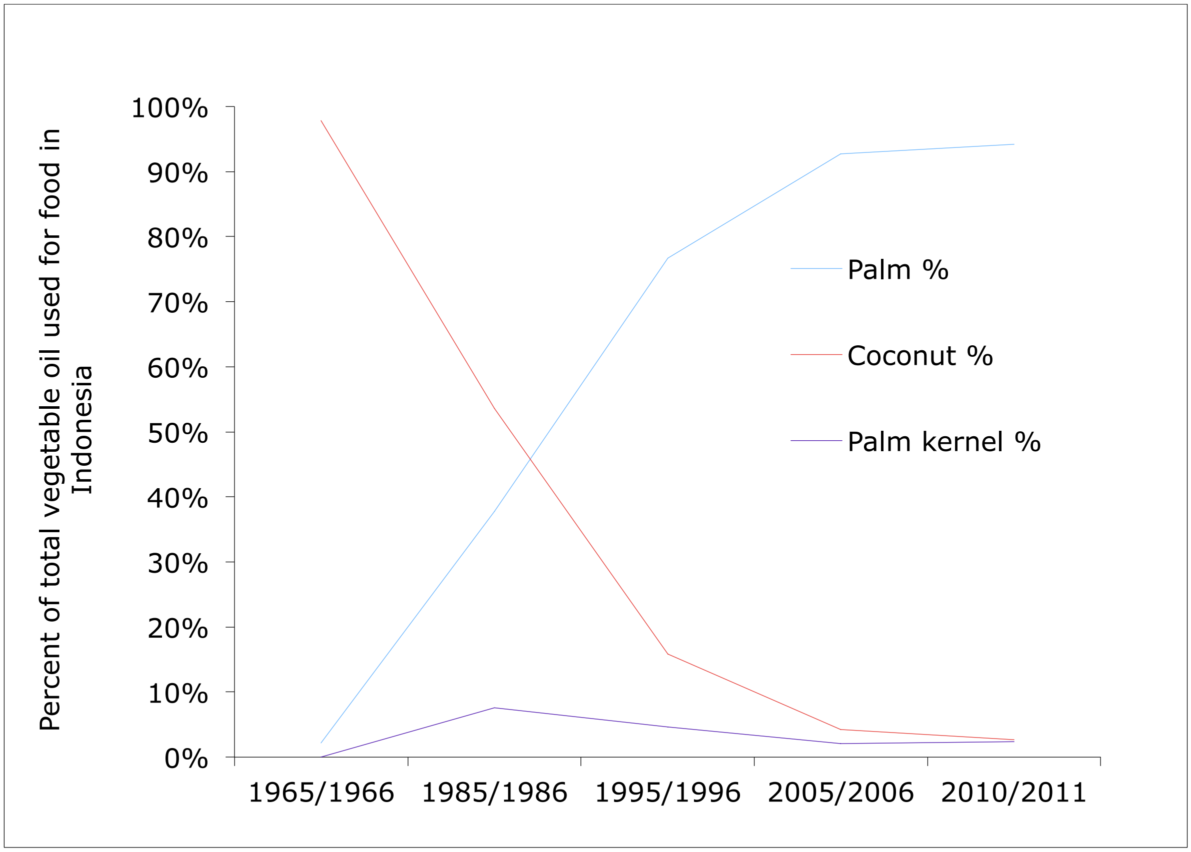

Figure 3-8. Palm oil has displaced coconut oil for cooking in Indonesia. The red line shows coconut oil's declining share of total vegetable oil consumption - from 98% in 1965 to 3% in 2010 – while the blue line show's palm oil's share of the domestic cooking oil market growing, from 2% to 94%, over the same time period. Palm kernel oil, Indonesia's third most common vegetable oil, is shown in purple. Source: (USDA, 2011b)

The impact of substitution on higher per capita palm oil consumption can be approximated by multiplying the change in palm oil's share of total vegetable oil consumption by the current level of vegetable oil consumption. This calculation is essentially the difference between the current amount of per capita palm oil consumption and the amount that would be consumed if Indonesians consumed palm oil and other vegetable oils in the same proportions as they did historically. The shift towards palm oil, away from coconut oil, explains an impressive seventy percent of observed per capita palm oil consumption growth in Indonesia (see figure 3-9) and more than half of total demand growth.

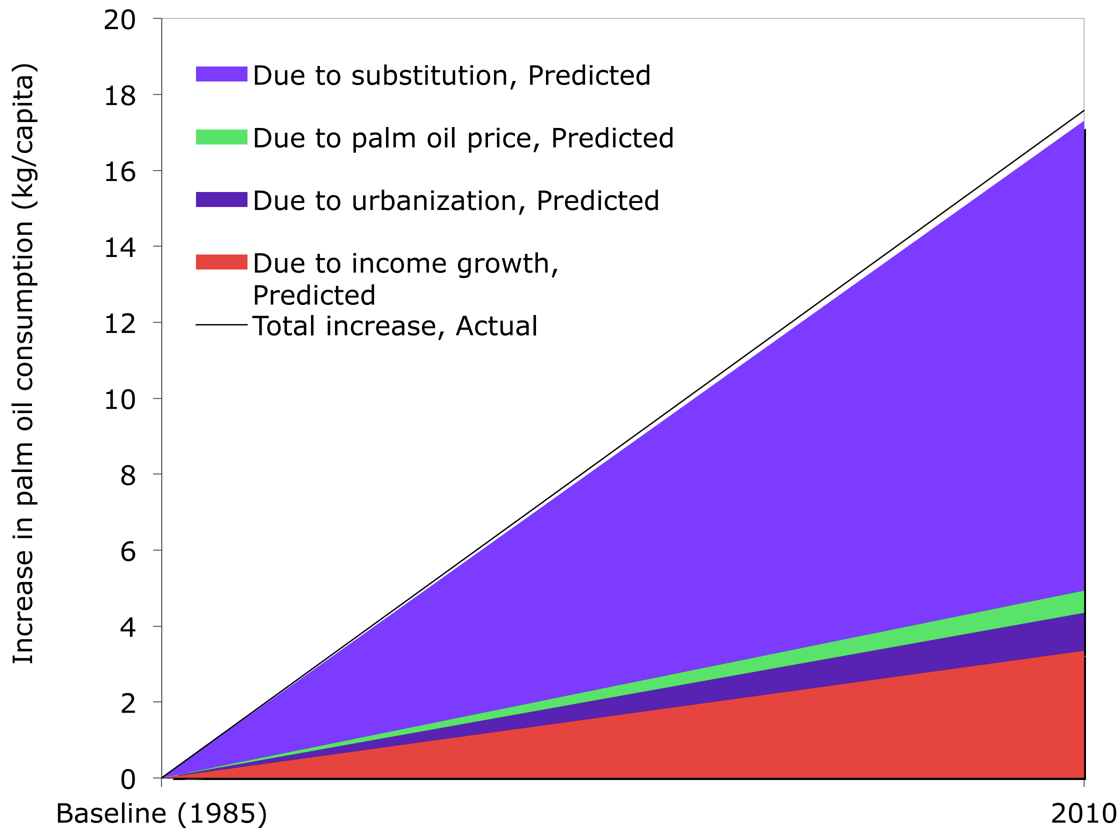

Figure 3-9. Results of a model explaining per capita palm oil consumption growth in Indonesia, 1985 - 2010.
Income elasticity = 0.8; Price elasticity = -0.5; Urban multiplier = 0.2. Source data: (Global Financial Data, 2011; USDA, 2011b; World Bank, 2010)

What drove this substitution trend? Coconut oil has become cheaper relative to palm oil in the last fifteen years but still remains the more expensive vegetable oil. That coconut oil is more expensive makes it puzzling why Indonesians historically consumed coconut oil instead of palm oil, especially since Indonesia's palm oil production in the 1970s was sufficiently large to meet the majority of Indonesia's consumption. Instead of exporting coconut oil, which would have earned more foreign exchange, Indonesia exported palm oil. The analysis that follows shows how sociological factors such as: local production trends, international trading patterns, innovations in crude palm oil (CPO) processing capacity, and a concerted national and international policy effort all affected cooking oil consumption patterns in Indonesia, facilitating Indonesia's switch from coconut oil to palm oil.

The role of trade and policy

Cooking oil is one of Indonesia's nine 'essential' food commodities; the government obligates itself to ensure sufficient cooking oil supplies. As a result, government policy has forcefully inserted itself into domestic production, marketing, and price formation. Policy and market forces together created a dramatic transformation: from the late 1960s through the 1970s, Indonesia exported some palm oil and was essentially self-sufficient in coconut oil, increasing its coconut oil production on pace with domestic consumption. Indonesians began consuming palm oil in the late '70s and early '80s until it eventually began displacing coconut oil demand. By the mid 1980s, Indonesia was exporting coconut oil into the world market (see table 3-7 for a summary of these developments). Meanwhile, palm oil production grew exponentially in Indonesia, permanently surpassing coconut oil production in 1982. Five years later, in 1987, palm oil consumption permanently surpassed coconut oil consumption (see figure 3-10). The following section describes political and technological developments that were crucial in promoting Indonesian palm oil production and consumption.

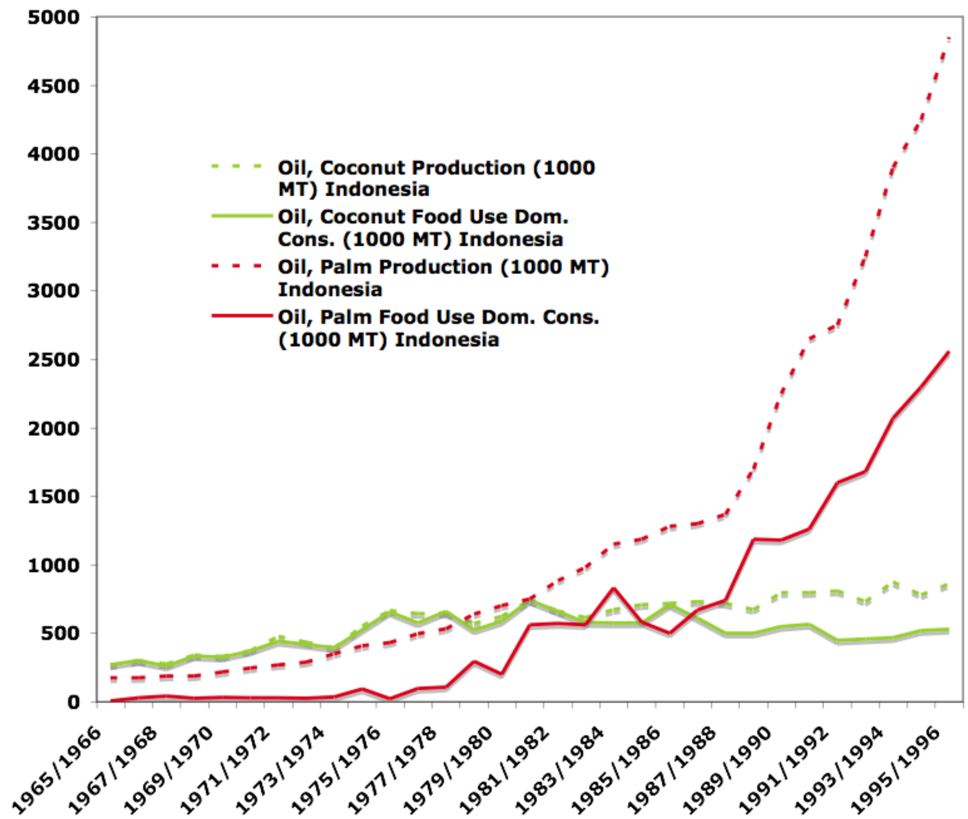

Figure 3-10. Palm oil versus coconut oil production and consumption in Indonesia.

Palm oil, in red has increased dramatically in terms of both production (dotted) and consumption (solid). Coconut oil, in green, has seen level production (dotted) and slightly declining consumption (solid). Palm oil consumption permanently surpassed coconut oil consumption in 1987. Source: (USDA, 2011b)

Table 3-7 Summary of Indonesia's vegetable oil transition.

Period	Before 1974	1974 – 1985	After 1985
Production trends	Self-sufficiency in coconut oil production (no coconut oil exports). Slightly less crude palm oil production, all of which was exported.	Palm oil production expands.	Indonesia becomes world's largest palm oil producer
Consumption trends	Only coconut oil	Becoming equal shares	Becoming mostly palm oil
Price and policy environment	Failed attempt (Repelita 1) to boost coconut oil production. Fractionation economics for palm oil become favorable in 1973.	Promotion of nucleus-estate schemes. Concerted government intervention in pricing and distribution.	Indonesia signs GATT in 1985 Tariff and quota structures favor coconut exports.

Early period, before 1974

Throughout the 1960s and 1970s, Indonesia produced enough palm oil to meet about eighty percent of its domestic cooking oil needs; yet, it exported most of this production in the form of crude palm oil (CPO). The lack of domestic palm oil consumption during this period is surprising in light of Indonesia's current appetite for palm oil and doubly surprising in light of the high price that coconut oil, if exported, would have fetched on the world market.

In the 1960s and early 1970s, Indonesians used coconut oil. Peanut oil supplemented edible oils a tiny bit, but by and large all cooking oil came from coconut. Coconut production was distributed across Indonesia's outlying islands on small farms averaging 1.5 Ha in size (Gwyer & Avontroodt, 1974). These farms were minimally productive: coconut production rose, slowly, just enough to keep up with domestic consumption. During *Repelita* 1 (1969 – 1974), Indonesia's first economic development plan, Indonesia's government underwent an unsuccessful effort, with the help of international donors, to boost coconut production (World Bank, 1985). The plan seems to have failed for several reasons: coconut farmers were remote and hard to reach; new coconut trees that did make it into the ground were often planted in unsuitable terrain; and the project had serious management problems (World Bank, 1985).

Another obstacle to Indonesian coconut production during this period was the organization of Indonesia's copra processing industry. Coconut oil consumption can take two forms: Fresh nuts can be processed using minimal technology on the farm to produce klentik oil; or, copra (dried coconut meats) can be processed at an industrial facility. Klentik production is less efficient but was expanded because copra-processing factories on the island of Java enjoyed a monopsony that effectively depressed farm-gate coconut prices. Approximately equal shares of coconut production went to direct local consumption (either as fresh coconut or klentic oil) and to copra production with the share of copra production rising over time (Gwyer & Avontroodt 1974, p.84, Table 5) (Gwyer & Avontroodt, 1974).

Despite coconut farms' remoteness and their minimal productivity, coconut farming remained attractive to farmers because it was flexible in the face of drought or price shocks. Unlike oil palm fruit, coconuts can be consumed on-farm in response to low market prices. And, coconut farmers often manage their trees concurrently with rice or other field crops that have complementary labor requirements, a diversification strategy that serves to minimize risk.

Palm oil, meanwhile, grew on large government-owned plantations and was exported rather than consumed domestically. In 1968, Indonesia's government nationalized private estates[20] in an attempt to capture a larger share of export earnings. At the time, palm oil made up about five percent of total agricultural export earnings (Food and Agriculture Organization (FAO), 2011). Exported palm oil took the form of crude palm oil rather than edible refined oil. Indonesia had some refining capacity: In 1974

[20]

there were four known fractionation plants in Indonesia that could separate liquid palm olein (used for cooking oil) from solid palm stearin; two of these factories were possibly in operation. One factory had a capacity of 9,000 tons of crude palm oil per year. These processing plants faced both management and economic problems that kept them from being successful. Of the small amount (28,000 tons) of palm oil that did not go to export, 15,000 tons went to solid baking fats and margarine while the remainder went to soap (Gwyer & Avontroodt, 1974).

Indonesia's vegetable oil system - marginally productive coconut oil for domestic consumption, crude palm oil for export - became unsustainable in 1973. At this time, a domestic drought, coupled with a global soybean shortage that sent international coconut prices soaring, forced a spike in Indonesia's domestic cooking oil price. Strict export controls in an archipelago with porous borders were of little help. Coconut oil had previously fetched a higher price than crude palm oil in the world market, but this price differential grew going into the mid 70s. Palm oil fractionation was not profitable in 1972, but at 1973 prices, it was. Additionally, the foreign exchange savings to be had by exporting coconut oil while consuming palm oil domestically were large.

Struggling to fill the domestic consumption gap for cooking oil, keep prices low, and avoid importing coconut oil from the Philippines, Indonesia's government looked to palm oil. Indonesia's second planning period (Repelita II), from 1974 – 1979, focused on agricultural development, infrastructure, and development in Indonesia's outlying islands – palm oil was central. Thirty-five percent of the funds for this development program came from foreign international sources, including the World Bank and the Asian Development Bank.

Middle period (transition), 1974 - 1985

The period from 1974 to 1985 saw a transformation in Indonesian diets as palm oil gained acceptance as a cooking oil. In the early 1970s, Indonesia's palm oil exports had been un-refined and unsuitable for cooking (palm oil was used domestically for some soap and a tiny amount of margarine / solid fat consumption). Price changes made palm oil refining profitable, but only if Indonesians who were not accustomed to eating palm oil could be convinced to substitute towards it. Indonesia's plantation ministry promoted palm oil as a substitute for coconut oil because it was locally grown (Chaudhuri 1994). Simultaneously, aggressive production policies produced steady palm oil output growth on new nucleus-estates, keeping prices low. A concerted ministry-sponsored marketing effort, coupled with favorable economics, did the trick: by the mid 1980s, domestic palm oil consumption was on par with coconut oil consumption and Indonesia was a significant palm oil exporter.

Consumption

As domestic coconut oil demand grew in the 1970s, the government looked to palm oil to 'fill the gap.' Other vegetable oil candidates were not as promising: palm kernel oil (PKO) shares more properties with coconut oil than palm oil does, but the quantity is relatively small compared with palm oil (and it is more expensive). Peanut oil, which, unlike palm oil in the 1970s, already supplied a small amount of cooking oil, had similar problems with scale. Rice-bran oil had problems with scale, rancidity, and transportation.

Palm oil, too, was not a perfect candidate. In order to achieve a significant market share, palm oil had to overcome issues of taste, color, fractionation, and refining. At first, refineries blended palm oil with coconut oil or flavored the palm oil to make it more palatable (Piggott, Parton, & Treadgold, 1993). Fractionation was critical because without fractionation, palm oil's semi-solid nature could remind consumers of pork fat – not an attractive quality in a predominantly Muslim society. In 1981, Indonesia had a fractionation capacity of 1 million tons of palm oil running at fifty percent capacity (World Bank, 1985). Further, refining technologies were critical for palm oil's success as a cooking oil. Refining was a relatively expensive process; nevertheless both private and state-owned factories received new investments. Palm oil had to be refined from red to pale yellow and deodorized to make it less different from coconut oil. Even after being refined and deodorized, palm oil's yellow color stood out. A government-funded marketing campaign originated the name '*kencana'*, Javanese for 'golden,' to make palm oil seem more familiar and appealing to consumers. In addition, palm-based cooking oil was marketed to industrial *krupuk* (cassava chips) manufacturers who were more sensitive to price and less sensitive to appearances. Palm oil's frying properties proved to be tremendous in this regard, and palm oil came to be considered of higher quality than locally-distributed coconut oil.

By 1981, Indonesia's 1.1 million ton domestic cooking oil market comprised a combination of palm oil (39%), coconut oil (50%) and palm kernel oil (PKO) (11%). Commentators at the time suggested that coconut oil retained a firm hold on the market. 60-80% of coconut oil consumption was "not open to ready substitution" (World Bank 1995) because 50-70 % of coconuts are consumed fresh and 15-25% are used as cooking oil where the lauric acid content is required. The cross-elasticity between coconut and palm oil was predicted to diminish with increasing substitution; subsequent time periods proved this prediction to be false.

Domestic vegetable oil production

Indonesia undertook large and sustained investments in tree crops during *Repelita* 3 (1979 – 1984), planting approximately 178 thousand new hectares of coconut and 121 thousand hectares of new oil palm, again with World Bank assistance (World Bank, 1985). Overall agricultural investment was large, sustained, dominated by foreign capital, and focused on tree crops more than food crops (World Bank, Agricultural Operations Division, 1992).

Palm oil production flourished during this period while coconut oil production stagnated. Indonesian palm oil production received a massive boost from the nucleus estate scheme (NES) that began in 1977. NES had both a production objective - to boost output and facilitate technological transfer - as well as the broader political-economic objectives of developing land and settling transmigrants in Indonesia's outlying islands (Booth, 1988). Plantations under this scheme tended to be large: although there was a ban on foreign land ownership and a legal limit on land holdings by Indonesians, estates could obtain permission to use land that they did not 'own' (World Bank, 1985). The scheme did promote some smallholder development: Indonesia's first smallholder palm oil plantations were established in 1978 under the NES; and, land titles for smallholders could be granted at the discretion of the state-owned plantation company (PTP) (WB 1985 p. 16). Still, by 1984, only 3.5 million out of a billion tonnes of palm oil production belonged to smallholders (Piggott et al., 1993). In terms of land, palm oil plantations were 2% smallholder-owned, 28% private, and 70% government-owned (World Bank, 1985).

Coconut oil production did not benefit from a similar organizational transformation. Production remained dominated by smallholders who undertook only minimal new plantings. Between 1980 and 1985, the average age of coconut trees increased and production remained stable. Coconut production did benefit from higher yielding hybrid seeds starting in 1979 (Piggott et al., 1993).

Pricing and trade policy

As a whole, palm oil exports nearly doubled through the late 1970s to four hundred thousand tons before the government intervened in an effort to lower domestic prices and ensure domestic availability of cooking oil, a key staple. Indonesia's government manipulated prices and distribution channels through a constantly changing set of regulations that included: 1) export quotas, which were set at 5% in 1978 and subsequently relaxed; 2) direct domestic price controls that were in place from 1978; 3) export taxes; 4) export bans; and 5) regulation of all PTP sales and domestic sales from private processors (World Bank, 1985). Processors received monthly allocations of crude palm oil to purchase from producers, who were required to ship at a fixed price. Then palm oil was distributed through a system of exclusive (and profitable) distribution rights. Locally powerful distribution monopolies served as a reward system for friends of the Suharto regime and further established palm oil as the dominant cooking oil (Peter Timmer, personal communication). This distribution system was applied similarly to wheat flour and sugar (in addition to vegetable oil), as a successful strategy for rewarding political cronies.

Any remaining palm oil that was not allocated to the domestic market could be exported (WB 1985). In 1978, the first year that the government regulated edible oil exports, 36% of total palm oil production was explicitly allocated to the domestic market (WB 1995). The following year, in 1979, government policy allocated sixty percent of palm oil production to domestic use at below market prices (Piggott 1993). By 1981 government requirements forced almost all palm oil onto the domestic market. Exports remained restricted in 1983 to prevent price increases (Piggott et al., 1993). In 1984, Indonesia suffered $369 million dollars in forgone export earnings due to restrictions on palm oil exports (World Bank 1995).

Efforts to lower coconut oil prices depressed local production – selling prices increased by only 2% - but failed to keep prices low for consumers. Copra was taxed at the farmgate and, in 1976, Bulog (the national logistics agency) imported copra and sold it at a loss to decrease domestic prices (Piggott 1993). In addition, because all coconut processing was located on Java, processors had impressive market power. Copra sold for $140 at the farmgate price compared with a $298 copra equivalent price for cooking oil (World Bank 1985).

Current consumption (1985 – present)

Most recently, palm oil has come to dominate Indonesian vegetable oil production and consumption. Market regulations are more relaxed even as cooking oil retains it status as a strategic commodity and essential food staple.

Tariff structures further encouraged substitution away from coconut and towards palm oil. In 1987, Indonesia reversed its policy strategy of retaining coconut oil and exporting palm. Palm oil faced a 10% export tax in 1989 (Piggott 1993), plus (despite Indonesia signing the GATT in 1985) quotas that forced palm oil onto the domestic market at below-export prices (Piggott 1993). In 1997, export taxes on CPO, RBD palm[21], crude olein and RBD olein (palm cooking oil) were eased as part of a deregulation package[22]; but, in 1998, the Asian financial crisis induced an export ban on CPO, all derived olein and stearin products, and palm kernel oil. This ban encouraged smuggling, depressed foreign exchange earnings, and hurt the coconut oil industry. A tax on coconut oil had to be introduced because palm oil was being disguised as coconut oil to avoid export taxes (Marks, Larson, & Pomeroy, 1998).

As trees matured, palm oil production surged despite unfavorable export policies. The palm oil plantings undertaken starting in 1984 as part of Repelita 4 were 'the most ambitious ever attempted for these crops in the world' (World Bank, 1985). At the end of the campaign, Indonesia boasted 18% of world production of 5.5. million tons with a low-age distribution of trees (World Bank 1995).

Domestic processing capacity surged as domestic crude palm oil production grew and less crude palm oil was exported to Malaysia and other countries. As part of its industrial strategy, Malaysia subsidized refining capacity, which delayed the development of Indonesia's domestic refining capabilities. Whereas Indonesia had only a small handful of processing factories in 1974, even fewer of these were in

[21] Refined, bleached, and deodorized palm oil
[22] Crude palm oil was taxed at 5%, RBD palm oil and crude olein at 4%; and RBD olein at 2%

operation. By 1981, Indonesia's CPO processing capacity had grown to one million tons; and by 2006, processing capacity had risen to more than 29 million tons (see table 3-8).

Table 3-8 Expansion of crude palm oil processing capacity in Indonesia. Values for 1997 and 2006 represent actual CPO use and are therefore minimum estimates of installed capacity. Sources: (Gwyer & Avontroodt, 1974; Indonesian Palm Oil Board, 2008; World Bank, 1985)

Year	Estimated volume of CPO processing capacity (tons)
1974	36,000
1981	1,000,000
1997	2,386,464
2006	29,017,060

Today, palm oil makes up 94% of Indonesia's edible oils market. Coconut oil makes up 3%, and palm kernel oil makes up a further 2%. Substitution away from coconut oil towards palm oil has even reached Indonesia's outlying islands where coconut oil used to be the dominant crop. In the Ujung Padang area of South Sulawesi, palm oil's market share went from zero in 1986 to 60% in 1996. In the 1970s this area had about 20 factories making coconut oil from fresh coconuts or copra; in 1996 there were only six, of which three produced cooking oil and three produced crude coconut oil. Coconut cooking oil factories on Indonesia's outlying islands, as on Java, came under pressure from quality issues, from higher world prices for raw materials (coconuts, copra, and crude coconut oil), as well as from palm export taxes imposed by Indonesia's government.

Future consumption growth

That so much of Indonesia's consumption growth has come from substitution during the past twenty-five years suggests that Indonesia will experience a dramatic slow-down in palm oil consumption growth in the future. Because over ninety percent of

Indonesian vegetable oil[23] now comes from palm oil, there is not much more coconut oil (or other oil) that can be replaced in people's diets. Going forward, any increase in palm oil consumption will come from higher overall vegetable oil consumption. Historically, substitution among vegetable oils accounted for half of Indonesia's growth in palm oil consumption. In the future, palm oil consumption growth will therefore be less than half as large given the lack of further substitution possibilities and declining consumption elasticities for vegetable oil. In fact, during the next twenty-five years, palm oil consumption growth will be about thirty percent of what it has been over the last twenty-five years. As population growth slows, as income growth slows, and as the income elasticity of palm oil consumption falls, overall vegetable oil consumption will fall. Lower vegetable oil consumption means lower palm oil consumption. Table 3-9 shows annualized rates of palm oil consumption growth between 1985 and 2010 along with predicted growth rates between 2010 and 2035 under both a baseline and a "high growth" scenario. In the baseline scenario, Indonesian palm oil consumption, which grew 9.4 percent per year, on average, over the past twenty-five years, is likely to grow by 2.9 percent per year between now and 2035. This estimate assumes constant prices, no urbanization effect, no further vegetable oil substitution towards palm oil, and population and income growth predictions in line with USDA (2010) estimates.

Under a "high growth" scenario where income growth over the next 25 years reaches 4.5 percent per year, palm oil prices continue to fall in real terms, and Indonesia's population reaches 300 million, palm oil consumption will grow at 3.8 %; still a significant growth rate but nothing close to the 9.4% annual growth rate that Indonesia has experienced since 1985. Even at these lower rates, however, Indonesia's total palm oil consumption in 2035 will be at least double that in 2005. Some of this increased volume will no doubt be met through yield increases, such as replanting of higher-yielding clones on existing plantations. Even so, the pressure to convert currently

[23] Used for food

forested land into palm oil production will continue to be substantial throughout Indonesia.

Indonesia's phenomenal growth in palm oil consumption has occurred through a substitution process that implies palm oil consumption can no longer grow at such a high rate. Other countries around the world have not yet reached Indonesia's high level of per capita palm oil consumption; whether they will depends on those countries' rates of economic growth and, as the case of Indonesia has shown, on the specific development policies that those countries choose to pursue.

Indonesia's demand growth for palm oil is not the whole story. Consumption patterns in China and India also matter for Indonesian oil palm producers, and, as the next chapter shows, those consumption patterns are drastically different. In addition, non-food uses for palm oil have the potential to upend the current structure of palm oil markets. The potential demand for palm-based biodiesel, at a favorable price, is practically infinite. Palm-based biofuels, in the case where diesel prices or government mandates provide adequate production incentives, would lead to a different qualitative conclusion about the future of palm oil demand. Markets for palm-based biodiesel are covered in chapter 5.

Table 3-9 Historical and predicted palm oil consumption.
Estimates and predictions are shown in blue. Future consumption estimates assume constant prices, no urban consumption differential, no further substitution, and an income elasticity demand of 0.5. Population and income growth estimates are informed by (USDA ERS, 2010).

	Value, 2010	Compound annual growth, 1985 - 2010	Value, 2035 Baseline	Compound annual growth, 2010-2035, Baseline	Value, 2035 High Estimate	Compound annual growth, 2010-2035, High Estimate
Population (millions)	230	1.40%	285	0.87%	300	1.07%
Income per capita (yr 2000 USD)	1124	3.50%	3085	4.12%	3380	4.5
Palm oil price (real USD)	486.12	-2.00%	486	0%	293	-2%
Urbanization rate	52.60%	2.80%	52.6	0%	52.6	0%
Fraction of vegetable oil from palm	94.19	3.70%	94.19	0%	94.19	0%
Estimated price elasticity	-0.5				-0.5	
Estimated urban differential	1.2					
Estimated income elasticity	0.8		0.5		0.6	
Palm oil consumption (kg per capita)	20.66	7.90%	34.4	2.06%	40.3	2.71
Palm oil consumption (total tonnes, thousands)	4750	9.40%	9804	2.94%	12090	3.81%

Appendix to chapter 3

Street Food and Palm Oil Consumption: A Bogor Case Study

Introduction

Walk out of the train station in Bogor, Indonesia, and crowded among the pedestrians you will find a long row of food carts. These mobile food vendors – *kaki limas* or larger *warung tendas* – are common along the sides of Bogor's streets wherever people might congregate. The vendors sell a wide variety of crispy, fried treats that make up an important (and delicious) source of caloric energy in Indonesia's growing urban centers.

Palm oil's low cost and good frying properties make it a ubiquitous ingredient in Indonesian street food. This appendix describes a case study from the city of Bogor, Indonesia that sheds light on street food as a source of palm oil demand. One hundred and ninety-five street food vendors were interviewed about their businesses to find out: (1) What is palm oil's role in this sector of the economy? (2) How important are palm oil price changes to the livelihoods of street vendors? (3) How big is street food's contribution to palm oil demand?

The survey is especially relevant in the context of Indonesia's rapid urbanization trend. The United Nations Population Division estimates that by 2035, 66 percent of Indonesia's population will be urbanized – including, perhaps, the entire population of Java (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2012; USINDO, 2012). As discussed in chapter 3, Indonesia's national socioeconomic survey (SUSENAS) does not adequately capture vegetable oil consumption differences between urban and rural areas because the SUSENAS measures only direct food consumption. Indirect food consumption, such as cooking oil consumption via fried, pre-prepared foods, does not appear explicitly in the national surveys. Since urban residents are more likely to consume pre-prepared meals outside the home (Chapman, 1984), and since these prepared meals are heavy in cooking oil, urban palm oil consumption is likely to be higher than the national socioeconomic survey reports. This line of reasoning supports the relatively large urban palm oil consumption effect incorporated into chapter 3's palm oil demand model. The higher street food consumption that is associated with urbanization leads to higher palm oil consumption.

Methods

We chose four areas of the city that were known as popular areas for street vendors and surveyed each vendor in those areas during the busiest hours of the evening (when vendors were most likely to be present). Our team of enumerators comprised seven college and masters students from the Institut Pertanian Bogor. The surveys were carried out on 8 occasions over two months between July 14 and August 11, 2009. In total, 194 enterprises were surveyed.

A three-part survey captured vendors' socioeconomic characteristics and palm oil's role as a food ingredient in the prepared food that vendors sold. Questions were both multiple choice and open-ended, covering: vendor and employee characteristics; vendor-reported input price trends; purchased quantities of food inputs; coping responses to high palm oil prices (higher menu portions, smaller portions, new recipes); and profitability.

Results

Vendor characteristics

Bogor's street food vendors tend to be young men with several years of experience selling prepared food (see table A-1). Eighty-eight percent of the vendors surveyed had no other source of employment.

Table A-0-1 Vendor characteristics by survey location

	Jambu Dua	*Pajajaran*	*Jembatan Merah*	*Bogor Trade Mall*
# Vendors	100	89	64	73
% Male	75%	90%	94%	97%
Age (mean)	26	28	32	32
Yrs. Experience (mean)	4.80	4.84	8.78	8.04

Palm oil purchases

On average, each vendor purchases 50 kg (57 liters) of palm oil per week. Palm oil is the most common purchased input (purchased by 79 percent of vendors), followed by flour (purchased by 47 percent of vendors) and kerosene (purchased by 45 percent of vendors) (see figure A-1). On a cost basis, palm oil is the third most expensive food input, as a fraction of total input costs, after poultry and tofu (see figure A-2).

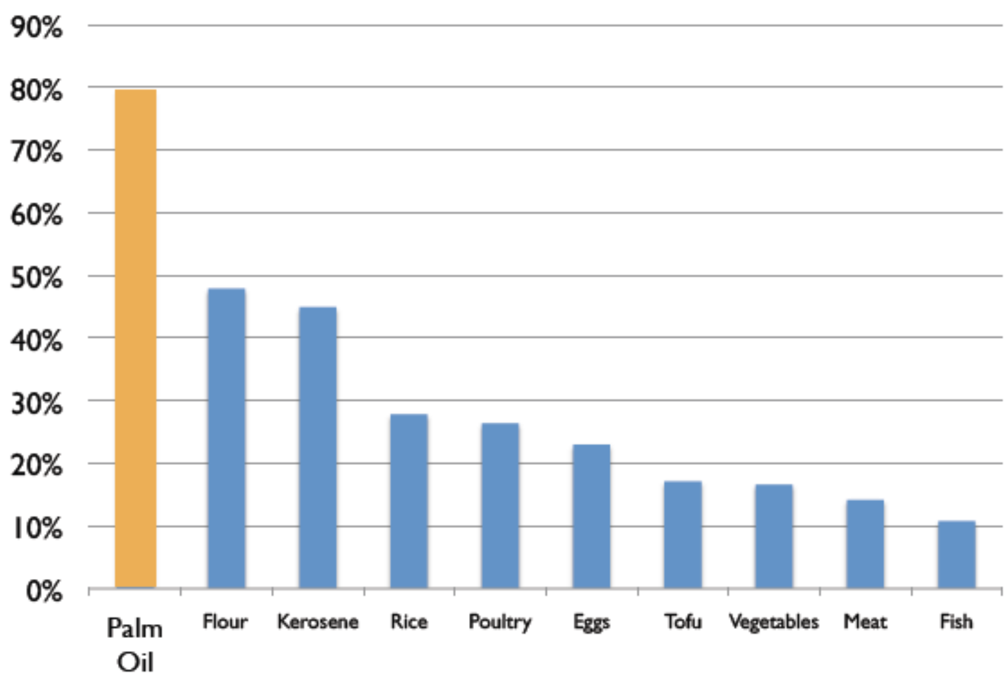

Figure A-1 Percentage of vendors purchasing food input

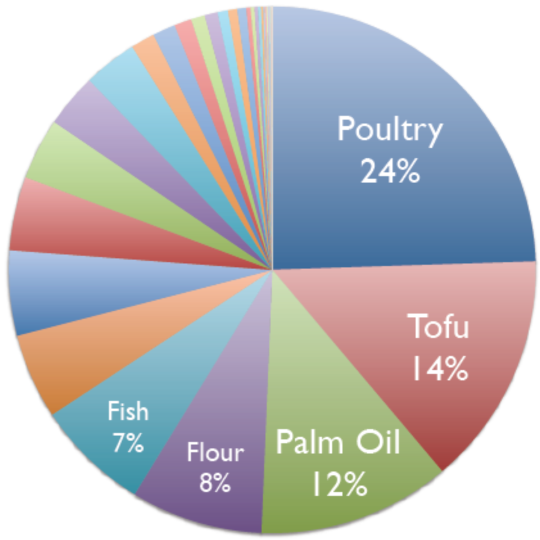

Figure A-2 Percentage of input costs, all vendors

Responses to fluctuating prices

Eighty percent of vendors reported profit declines in 2008. During the same year, vendors faced price increases for cooking oil, on average, of thirty-seven percent. Despite the large increase in cooking oil prices, vendors rated cooking oil price changes as unimportant to profitability relative to (1) their food stall's location, (2) the weather, and (3) rising fuel prices. Instead of taking a loss when cooking oil prices increased, some vendors chose to reduce portion sizes or raise prices.

Discussion

Vendors' ability to respond to changing cooking oil prices through higher selling prices or smaller portions implies that these urban jobs are less vulnerable to an input price change. Chapman (Chapman, 1984) argues that Indonesia's street food sector provides valuable jobs, especially for women. Interestingly, I found that food vendors were mostly men.

Vendors' responses to higher cooking oil prices are worrisome if smaller portions and higher prices for prepared foods negatively affect consumers. Bijlmer (Bijlmer, 1992) finds that street food enhances calorie intake and dietary diversity, especially for school children. In addition, white-collar workers and informal sector workers for whom cooking is expensive (in terms of time and fuel) rely heavily on street food for their meals (Tinker, 1997). A previous study found that Bogor's street food economy accounts for twenty-five percent of household food expenditures, consistent across income levels (Chapman, 1984).

Because street food makes up a substantial portion of urban household food consumption, the cooking oil contained in street food is essential to account for in urban diets. Survey results suggest that vendors purchase large quantities of palm oil that are not directly recorded in household consumption statistics, and that the cooking oil consumption data collected through Indonesia's standard household surveys are likely to be underestimates.

Chapter 4 Pig feed, policy, and contrasting patterns of vegetable oil consumption in China, India, and Indonesia

Introduction

Indonesia's extraordinary rise in palm oil consumption between 1985 and 2010 has had an impressive impact on global palm oil demand, in its own right. The question remains, to what extent is Indonesia's experience representative of cooking oil consumption trends in other fast-growing Asian countries? Has per capita palm oil consumption grown as quickly in China and India as it has in Indonesia? Why or why not? Further, while Asia has accounted for 67 percent of the increase in global palm oil consumption since 1985, over the next twenty-five years, consumers in other regions, particularly in Africa, are likely to incorporate a growing amount of palm oil into their diets. This chapter attempts to understand future trajectories of palm oil demand growth by drawing lessons from the different experiences of Indonesia, China, and India.

Causes of higher consumption

The most predictable factors leading to higher palm oil consumption – in Asia and elsewhere – are income and population growth. These two factors alone predict large global increases in palm oil demand over the coming twenty-five years.

Income effects

Higher incomes cause greater food consumption in the aggregate: as individuals and countries grow richer, they spend more money directly and indirectly on staple grains, edible oils, vegetables, and meat (even as the share of food in total budget expenditures declines). This relationship is particularly true at lower levels of income per capita; at high enough levels of income per capita, consumption levels off (the iron "law of the stomach") (Timmer, Falcon, & Pearson, 1983b). For vegetable oils, how much will consumption grow in the future? What is the relevant range of consumption levels that we can expect?

The relationship between income and food consumption varies for different commodities and for different consumers. Dewnowski and Popkin (1997) note the 'westernization' of global diets: over time and as countries grow richer, imports of animal fats increase, in the form of meat and milk products. In developing countries, however, Dewnowski and Popkin note that this 'nutrition transition' typically begins with large increases in the domestic production and imports of oilseeds and vegetable oils.

Staple grains, such as rice, show income elasticities that are highest at low levels of income and then decline, even becoming negative, at high levels of income. Experts believe that rice at the global level became an inferior good in the late 1990s and that global rice consumption will start to decline by 2020 (Timmer et al., 2010). Meat products, in contrast, show higher income elasticities at high levels of income. The income elasticity of consumption for vegetable oils lies somewhere in between: it is higher than for grain crops, and lower than for meat. In China, the largest increases in pork consumption are taking place among middle- to high-income adults, while the largest increases in edible oils are happening among lower-income adults (Guo, Mroz, Popkin, & Zhai, 2000). The USDA measures a negative income elasticity of vegetable oil consumption for three wealthy countries: Luxembourg, Spain, and the United States (USDA ERS elasticity database). Currently, at the global median GDP/capita of USD 1400, fats and oils have an income elasticity of about 0.6 (USDA, 2005).

Across countries, the correlation between per capita GDP and vegetable oil consumption is weak. Although vegetable oil consumption tends to increase, at a declining rate, as countries get richer, there are large variations between countries at similar income levels. Denmark and Italy are two extreme examples: Denmark, with an average per capita income of USD 31,000 per year, consumes 6 kg/cap/year of vegetable oil while Italy, with an average per capita income of USD 18,000 per year, consumes 28 kg/cap/year – almost five times as much vegetable oil per capita (FAOSTAT). Diets in Italy and Denmark are different due to their different food traditions and cultures. While olive oil is an Italian kitchen staple, in Denmark dietary fat is more likely to come from butter or pork. Danish diets derive one quarter of their fat calories from vegetable oils and three quarters from animal fats; whereas, Italian diets derive 81 percent of their fat calories from vegetable oils (FAO FBS).

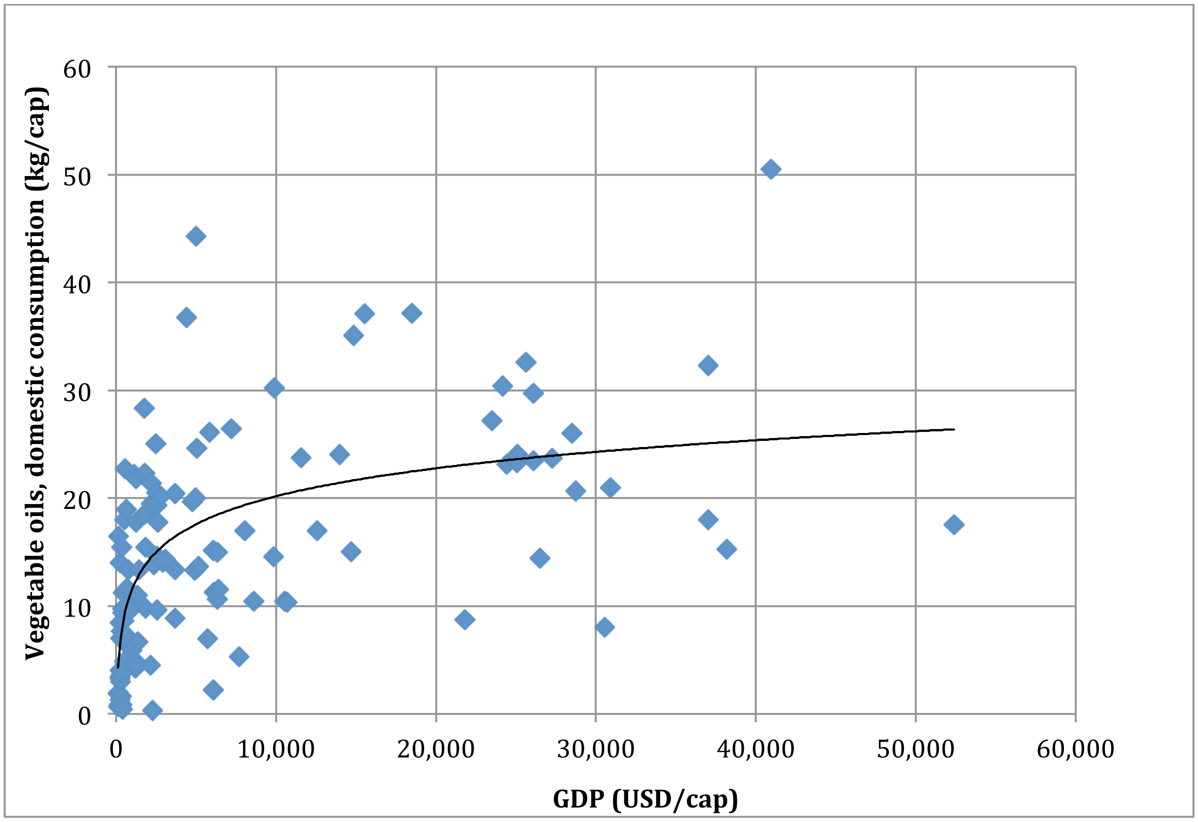

Figure 4-1. Relationship between income and vegetable oil consumption for 120 countries.
Oil consumption varies among countries at similar levels of GDP/capita. Slope of the logarithmic line of best fit suggests diminishing effect of income on consumption. The regression has the equation y = 3.75 ln(x) -14.4, with $R^2 = 0.377$ and t = 8.44. Data sources: World Bank WDI, USDA 2009 data; FAO Food Balance Sheets; Author's calculation.

Figure 4-1 shows per capita vegetable oil consumption by country, ranked by per capita income. The data set is a combination of USDA "domestic food consumption" data, FAO Food Balance Sheet "food supply" data, and World Bank population and GDP statistics. On its own, the USDA data set has sparse data points at higher income levels (USD 20,000-40,000 annual GDP per capita) because the USDA reports the European Union as an aggregate. In order to disaggregate consumption data for individual EU countries, weights were constructed based on data from the FAO Food Balance Sheets. The resulting, combined data set suggests that per capita vegetable oil consumption might begin to decline at the highest income levels, although there is enormous variation among different countries at the same level of per capita GDP.

While it is clear that vegetable oil consumption increases more slowly as countries get richer, it is not clear at what income level vegetable oil consumption "tops out." The logarithmic line of best fit in figure 4-1 has the equation $y = 3.75\ln(x) - 14.34$, with R-squared equal to 0.377 and standard error equal to 0.44. Vegetable oil consumption tends not to increase much with income at the highest income levels, but there is still a wide range of vegetable oil consumption among wealthier countries. For countries with annual per capita incomes above USD 5,000, mean vegetable oil consumption is 20 kg / capita with a standard deviation of 9.9. For countries with annual per capita incomes above USD 10,000, mean vegetable oil consumption is 23 kg/capita with a standard deviation of 9.7 (data from USDA, FAO FBS, and WB WDI) (see table 4-1).

Table 4-1 Variation in vegetable oil consumption among countries.
Data source: FAO FBS, USDA, World Bank WDI
Vegetable oil consumption (kg/cap/year)

Income threshold	Mean	Std. Dev.	Countries
$5,000	20.48	9.94	45
$10,000	23.46	9.73	29

The relationship between fats and oils consumption (which includes animal fats such as butter) and GDP is not much more stable than the relationship between GDP and vegetable oil consumption. As mentioned previously, Italy consumes significantly more vegetable oil per capita than Denmark; Italy also consumes much more overall fat. Table 4-2 summarizes the high variation in animal fats 'consumption' among countries. The data do not measure actual consumption, but rather supply availability (production minus net exports) for each country.

Table 4-2 Variation in animal fat consumption among countries.
Data source: FAOSTAT

Animal fats supply (kg/cap/year)

Income threshold	Mean	Std. Dev.	Countries
$5,000	3.98	4.54	40
$10,000	3.09	3.64	25

The relationships between income and oil consumption have shifted over time, (Guo et al., 2000; Huang & Bouis, 1996). In China, the income elasticity of vegetable oil consumption increased the most among the lowest income Chinese between 1989 and 1993 (Guo et al., 2000). Popkin argues that higher income elasticities of vegetable oil consumption at lower incomes are evidence of a 'nutrition transition' that explains the 'double burden' of obesity and undernourishment in developing countries (Popkin, 2001; Popkin, 2011). At present, the limitations of existing data combined with large variations in culture and diets across countries make impossible any firm generalizations about income levels and vegetable oils consumption. Still, it seems unlikely that many countries, as they grow richer, will exceed vegetable oil consumption levels of 33 kg/cap/year.

Price effects

Real prices for food commodities have generally fallen over the past 25 years, but in more recent years prices have spiked back up. Figure 4-2 shows two different indices of real prices: an index of real food prices in red (Economist, GFD) and an index of fats and oils prices in blue (BLS, GFD). Food prices and vegetable oils prices have been tremendously volatile. However, over the course of the period that is relevant to this analysis, prices have been volotile around a steady average real price.

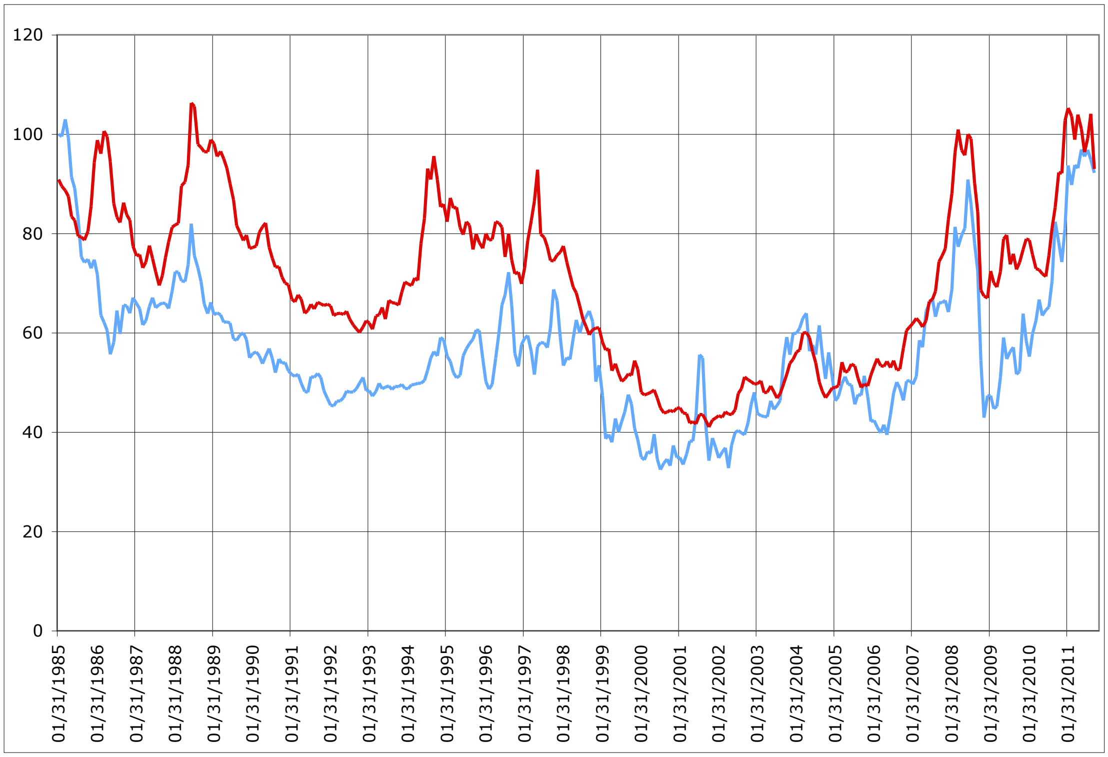

Figure 4-2. Indexes of real food (red) and fats and oils (blue) prices, 1985 – 2011. Source: BLS, Economist, GFD

Within the category of vegetable oils, palm oil has remained – with only minor exceptions, such as the period following the Asian financial crisis – the cheapest vegetable oil in international markets (see figure 4-3). Changes in the relative prices of different vegetable oils can drastically influence demand since vegetable oils are strong substitutes for one another. In the context of the global prices shown in figure 4-3, transportation costs and other barriers to trade play a significant role in determining the relative prices that consumers face in the marketplace.

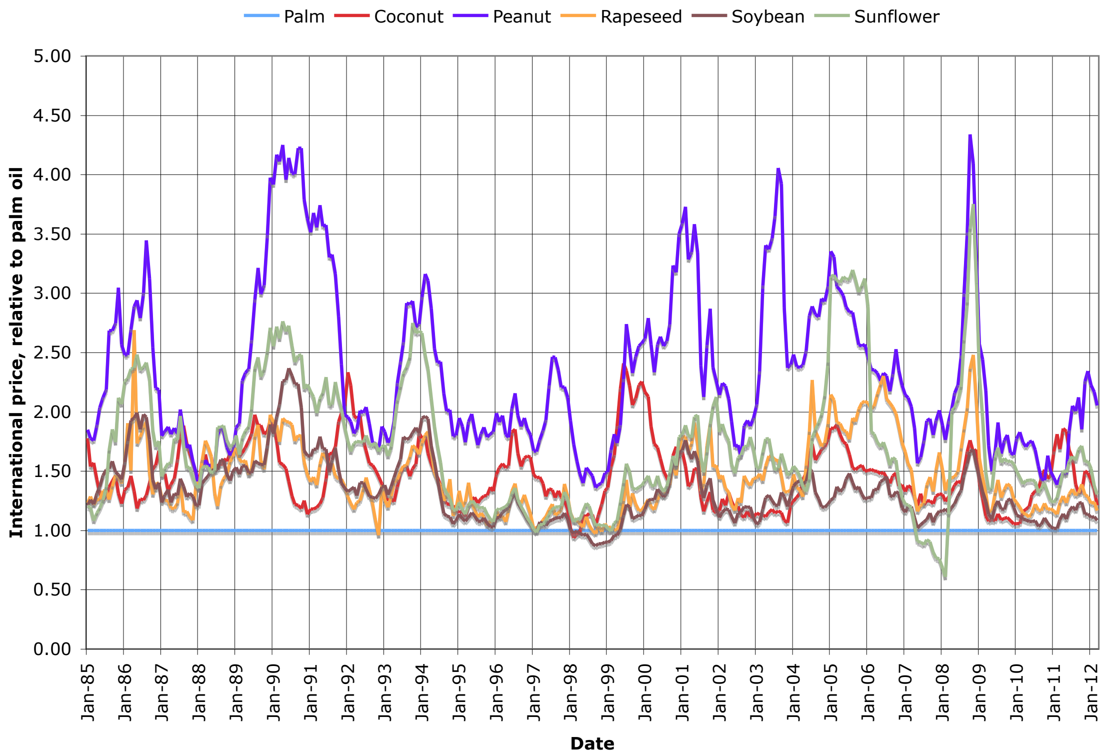

Figure 4-3. International prices of the major vegetable oils, relative to palm oil's price, 1985 – 2012.
Source: World Bank, IMF

Share effects

Demand substitution between vegetable oils has been an important trend not just in Indonesia, as discussed previously, but also for the world. Most agricultural commodities are linked to one another through substitution in production and consumption. Vegetable oils, however, tend to be particularly good substitutes for one another in consumption. Rice and wheat look and taste different, but refined soybean oil is difficult to tell apart, from a consumer point of view, from processed rapeseed oil.

One explanation for the surge in palm oil and soybean oil production since 1985 is that global diets are converging away from minor vegetable oils -- such as sunflower, cottonseed, or coconut -- towards two or three dominant varieties. This convergence trend is strong for the world as a whole and dramatic in certain individual countries, such as with the switch from coconut oil to palm oil in Indonesia, as discussed in chapter 3.

Palm oil's rise has been particularly dramatic in Asia. Since 1985, Asia has accounted for 69% of the world's palm oil consumption growth (see table 4-3): For Asia as a whole, palm oil has gone from being the least-consumed vegetable oil in 1985/6 to being the most consumed vegetable oil in 2010/11, following global trends. Soybean oil, which in 1965 was Asia's second least popular vegetable oil, is today the second most popular vegetable oil, while rapeseed and coconut oil have lost market share (see table 4-4).

Table 4-3 Asia has accounted for the majority of global palm oil consumption growth since 1985.
Source: (USDA, 2011b)

Region	Palm oil cons. 1985 (million tonnes)	Palm oil cons. 2010 (million tonnes)	Difference	Share of global consumption growth, 1985 - 2010
Asia	3.5	30.1	26.7	69%
Europe	1.0	5.4	4.5	12%
North America	0.3	1.1	0.8	2%
South America	0.4	2.3	1.9	5%
Africa	1.8	4.8	3.1	8%
Middle East	0.4	2.0	1.6	4%
Oceania / other	0.3	0.3	0.0	0%
TOTAL			38.4	100%

Table 4-4 Vegetable oils for food consumption in Asia.
Source: (USDA, 2011b)

	1965	1985	1995	2005	2010
TOTAL VEG OIL, Asia (1000 MT)	**2471**	**13722**	**26134**	**45618**	**59726**
Palm %	2%	19%	27%	33%	39%
Soy %	25%	18%	20%	28%	28%
Rapeseed %	43%	25%	23%	18%	16%
Coconut %	30%	10%	5%	2%	2%

Contrasting consumption patterns within Asia

Asia's experience illustrates the diversity of vegetable oil consumption patterns with respect to the composition of different vegetable oils in people's diets. In the future, which vegetable oils people choose to consume will have a dramatic effect on global production systems[24]. Three regions within Asia: East Asia, South Asia, and Southeast Asia, have experienced different trends in their sources of dietary fat. Southeast Asia started with the highest fraction of cooking oil from palm oil (35%) in 1985 and today has 80% of its cooking oil from palm oil. East Asia, in contrast, started with only 5% of cooking oil from palm oil in 1985 and today still has a minority of cooking oil (20%) from palm oil. South Asia falls in the middle: with palm oil accounting for half (49%) of total cooking oil consumption (see table 4-5).

Table 4-5 Vegetable oil and palm oil consumption for three Asian regions.
Source: (USDA, 2011b)

	1985		**2010**	
	Veg oil total (Food use, 1000MT)	Palm oil %	Veg oil total (Food use, 1000MT)	Palm oil %
East Asia	6118	5%	30554	19%
South Asia	5340	28%	20143	49%
Southeast Asia	2,264	35%	9029	80%

Indonesia

Indonesia exemplifies Southeast Asia's experience. Substitution away from minor vegetable oils towards palm oil has gone hand in hand with a massive expansion in production that is transforming rural landscapes. Population and income growth explain some -- about 24 percent -- of higher palm oil consumption between 1985 and 2010. This figure assumes a high average income elasticity of vegetable oil demand, for the period, of 0.8. A lower income elasticity estimate of 0.6 implies that income and population growth accounted for only 22% of total consumption growth.

[24] And vice-versa: increases in supply will cause prices to fall, raising consumption.

Substitution among vegetable oils – even in the absence of any population and income growth between 1985 and 2010 – can account for 26 percent of total palm oil consumption growth.

As discussed in chapter 3, palm oil's rising importance in Indonesian diets occurred as coconut oil consumption declined - the result of development policies in the 1970s and 1980s that specifically promoted palm oil production and consumption. Going forward, however, there is not much more substitution that can take place: 94 percent of Indonesian vegetable oil consumption currently comes from palm. Given the lack of further substitution possibilities towards palm oil, palm oil consumption growth in Indonesia over the next twenty years is likely to less than one third of what it was over the past twenty years (see table 4-6). Palm oil consumption growth in Indonesia will be determined by income growth, income elasticities, and population growth, but not by substitution away from other vegetable oils. Nevertheless, despite this change, total Indonesian palm oil demand is expected to double by 2035.

Table 4-6 Past and future palm oil consumption in Indonesia.
Source: USDA, author's calculations

	Growth rates		Levels	
	1985 – 2010	**2010-2035**	**2010**	**2035**
Consumption (kg/capita)	7.90%	2.06%	20.66	34.4
Total consumption (million tons)	9.40%	2.94%	4.8	9.8

India

For all of the palm oil in Indonesian diets, Indonesia is still only the second biggest palm oil consuming country in the world, in aggregate terms. India is the first. Unlike Indonesia, India imports 98 percent of its palm oil consumption (India is also the world's largest palm oil importing country). Palm oil consumption in India is, thus, heavily dependent on trade policy.

Palm oil imports into India are complicated by the fact that India ranks among the largest oilseeds producers in the world - along with the USA, China, and Brazil. Imported palm oil competes with domestically-produced oil crops such as cottonseed, soybean, rapeseed, and peanut. Although domestic production of these oilseed crops is high, India's productivity in oilseeds production is low – around 50% of the world average, for most oilseeds, and even lower for soy (see table 4-6). India's domestic oilseed producers are, by and large, small-scale farmers with limited resources who face erratic rainfall patterns. Less than 25% of cropped area for oilseeds is irrigated (Srinivasan, 2005). Together, cottonseed, soybean, rapeseed, and peanut account for 97% of India's oilseed crop (USDA, 2011b). As domestic production of these crops has failed to keep up with India's growing demand for vegetable oil, Indian vegetable oil imports, particularly palm oil imports, have soared (see figure 4-4).

Table 4-7 Oilseeds yields in India (tonnes / ha).
Source: (Srinivasan, 2005)

Oilseed	India	World Average	Highest
Soybean	0.85	2.29	3.28 (EU-15)
Cottonseed	0.59	1.06	2.07 (Australia)
Groundnut	0.59	1.02	2.13 (China)
Sunflower	0.62	1.18	1.73 (EU-15)
Rapeseed	0.75	1.49	2.96 (EU-15)

Palm oil is now India's most common source of fats and oils. The second most common source of fat in India is butter (ghee), for which Indians have a strong taste preference. India produces over 99% of its butter domestically (USDA, 2011b). Taste preferences also exist for traditional oilseed crops. At a sub-national scale, regional differences in crop production are reflected in regional consumption preferences. Groundnut oil is preferred in southern and western India, for example, whereas in the east and the north, rapeseed oil consumption is more common (Srinivasan 2005). Taste preferences for soybean and cottonseed oil are less pronounced. As a result, these oils often get made into vanaspati, a solid fat made by hydrogenating vegetable oils that then serves as a cheaper alternative to ghee. Vanaspati accounts for approximately 13 percent of vegetable oil consumption in India (Srinivasan, 2005).

Palm oil is not preferred for its taste (recall that in Indonesia, palm oil also fought an uphill battle against traditional preferences for coconut oil); however, if the price of palm oil imported by private traders is low enough and marketing costs are not too high, price-sensitive consumers will choose it over more expensive alternatives. Imported oils now make up almost half (47%) of India's vegetable oil consumption[25] (USDA, 2011b).

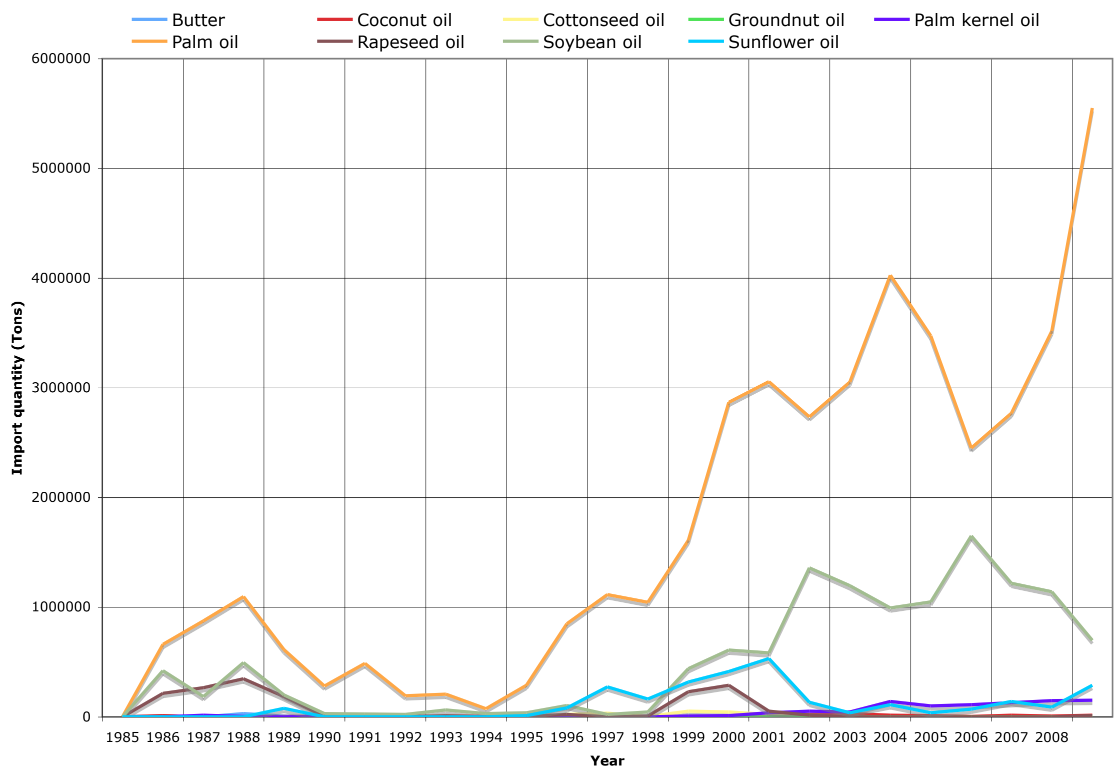

Figure 4-4. Indian vegetable oil imports, 1985 – 2008.
Imports have made palm oil India's most commonly consumed vegetable oil. In 1994, India took steps to liberalize its trading regime for oil. Data source: (USDA, 2011b).

Pre-WTO import substitution policies

Import policy, therefore, is an important determinant of Indian vegetable oil consumption patterns. From the 1970s until 1994, India's government had a state monopoly on edible oil imports: An inter-ministerial committee, taking into

[25] This is in contrast to the rest of India's food economy, where imports (and exports) are a small percentage of food expenditures (Reardon & Minten, 2011),

consideration domestic supply, demand, and balance of payments constraints, determined annual amounts to be imported by the Government State Trading Corporation (Hawkes, 2009; Persaud & Landes, 2006). Private companies were not permitted to import vegetable oils. Between 1989 and 1994, India undertook a special initiative, the 'Technology Mission on Oilseeds," to boost self-sufficiency in edible oils. In response, domestic oilseed production rose from 19 million tonnes in 1989 to a peak of 28 million tonnes in 1996 (USDA, 2011b). Consumption of domestic oilseeds -- including rapeseed, sunflower, and cottonseed – also increased during this period, as those oils slightly increased their shares of total oils and fats consumption (see figure 4-5).

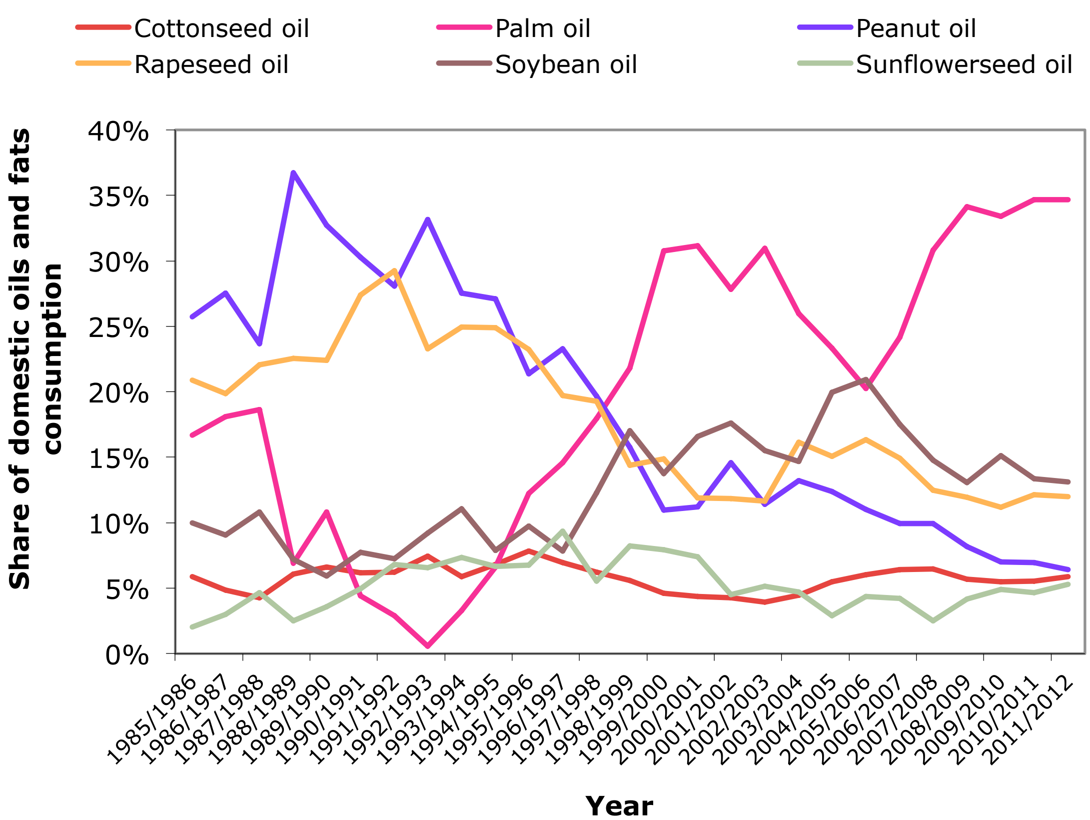

Figure 4-5. Fats and oils substitution in India, 1985 – 2012.
Source: (USDA, 2011b)

Increased trade liberalization after 1995

Starting around 1995, when India joined the World Trade Organization (WTO), the composition of Indian vegetable oil consumption saw dramatic changes. Imported palm oil quickly became the dominant source of Indian fats and oils consumption, while higher-priced, domestically-produced oils have seen their market share decline (Persaud & Landes, 2006) (see figure 4-5).

India's market access commitments under the WTO required the dismantling of India's state-run importing monopoly and the removal of quantitative restrictions on vegetable oils imports, opening up imports to the private sector. After these changes, private traders could respond to international price signals, importing freely subject to the tariff rate (initially set at 65 percent). Even in this more liberalized trade environment, tariff rates on imported vegetable oils remain high, in order to protect domestic producers and processors: crude palm oil faces an 80 percent applied tariff rate[26], while crude soybean oil faces an import tariff of 45 percent. Bound rates for palm oil and soybean oil – the highest possible tariff rates permitted under India's WTO agreement - are at 300 percent and 45 percent, respectively. The difference between India's bound tariff rate for palm oil (300%) and India's applied tariff rate (85%) implies that India has room to increase palm oil tariffs, should it so choose. The same is not true for soybean oil.

Despite the low bound tariff rate for soybean oil, palm oil is the most imported vegetable oil, not soybean oil. Palm oil companies, incentivized by the enormous potential volume of exports to India, have set their prices to remain competitive in the face of 35% higher tariff rates. These low palm oil prices are feasible because palm oil prices are lower at the point of origin and because transport costs are lower from Indonesia and Malaysia to India than they are from the USA or Argentina to India (Srinivasan, 2005). Despite the higher tariff on palm oil, soy oil and palm oil prices are competitive from year to year in the Mumbai market (see table 4-7). The binding

[26] Refined palm oil is taxed at 90%

WTO ceiling on India's soybean oil tariffs therefore determines a key vegetable oil price in the Indian domestic market with which both domestic oil producers and foreign palm oil producers are forced to compete.

Table 4-8 Annual average price registered for Mumbai market, Rs/Tonne
Source: (Solvent Extractors' Association of India, 2008)

	2006	**2005**	**2004**	**2003**	**2002**
Palm oil (RBD Palmolein)	40564	36418	40517	38057	33671
Soybean oil (SE refined)	39965	35726	42726	40602	34825

Future growth in palm oil consumption

India has grown substantially in population and per capita income over the past twenty-five years, and this growth is predicted to continue (see table 4-9). Without any change in current trade policy or the composition of Indian vegetable oil consumption, the population growth, income growth, and elasticity assumptions in table 4-9 imply an increase in Indian palm oil consumption of 4.6 million tons by 2035. This partial equilibrium model assumes that current palm oil price levels are sufficient to incentivize adequate production increases; i.e., that palm oil's price remains unchanged. In practice, historical prices have been highly variable and future prices are likely to be so as well.

Table 4-9 Indian palm oil consumption projection assumptions and previous-period averages.
Estimates, based on USDA projections and author's judgment, are shown in blue. Historical period averages from World Bank, USDA.

	1985-2010	2010-2035
Population growth	1.18%	1.10%
Per capita income growth	3.04%	6.00%
Income elasticity	0.9	0.15
Price growth	-1.40%	0%
Price elasticity	-0.5	-0.4
End-of-period share of palm oil in total oils and fats consumption	44.08%	60%
Share growth rate	2.34%	1.24%

Trade policy measures, such as lowering palm oil tariffs to the level of soybean tariffs, could have a dramatic effect on the composition of Indian vegetable oil demand. At the extreme, if cheap palm oil were to completely crowd out soybean production and other domestic vegetable oils (leading to a vegetable consumption profile similar to Indonesia's), then India could account for 19 million tons of additional global palm oil imports[27]. Given the harm that this much imported palm oil would inflict on domestic Indian farmers and oilseed processors, a more reasonable assumption is that palm oil's share of Indian vegetable oil consumption will rise to 60 percent, rather than 100 percent, by the year 2035. Under this assumption, per capita Indian palm oil consumption rises by 1.1 kg/cap and total consumption rises by 5.4 million tons (see table 4-8). If India's domestic oilseed industry cannot successfully shelter itself from competition with palm oil imports, then pressure on forests in Southeast Asia and other potential production sites could dramatically increase.

[27] Assuming 1.1% compound annual population growth, 6% income growth, and an average income elasticity of 0.15.

Table 4-10 Past and future palm oil consumption in India.
Source: USDA, author's calculations

	Growth rates		Levels	
	1985 – 2010	**2010-2035**	**2010**	**2035**
Consumption (kg/capita)	7.28%	2.14%	5.89	6.8
Total consumption (million tons)	9.06%	3.33%	10.0	15.4

China

After India and Indonesia, China is the world's third largest palm oil consuming country. Where Indonesia's vegetable oil consumption patterns originate from its domestic production and policies, and India's vegetable oil consumption patterns are partly the product of import duties, China's vegetable oil consumption patterns are shaped in large part by its livestock sector.

Like India, China is a large oilseed producer and also a large importer of vegetable oils (or seeds) to feed its growing population. One dramatic difference in the agricultural economies of India and China is China's growing livestock industry, particularly the pork industry. Substantial economic growth in China (see table 4-11) has contributed to a dietary transition away from staple grains (such as rice) and towards diets that contain more animal proteins and fat and more vegetable oil.

Table 4-11 Projection assumptions and previous-period averages, China.
Estimates, based on USDA projections and author's judgment, are shown in blue.
Historical period averages from World Bank, USDA.

	1985-2010	**2010-2035**
Population growth	0.64%	0.23%
Income growth	5.76%	6.00%
Income elasticity	0.9	0.1
Price growth	-1.40%	0%
Price elasticity	-0.5	-0.4
End-of-period share	18.36%	30%
Share growth	3.35%	1.98%

China's pork industry generates enormous demand for soybean meal. When soybeans are crushed to produce soybean oil, soybean meal is generated as a co-product, at the ratio of 4 tons of meal for each ton of oil. India has an excess supply of soybean meal, which the country exports (India exported 4.2 million tons of soybean meal in 2011) (USDA, 2011b). China, on the other hand, uses 47.6 million tons of soybean meal domestically, to feed its livestock sector. Soybean meal constitutes an important protein source in compound animal feeds that are used in pork production, in poultry production, and, increasingly, in aquaculture.

At the margin, demand for soybean meal affects how many soybeans are crushed - and, as a result, how much soybean oil is available. As China has grown in population and income, meat consumption – especially pork consumption – has increased exponentially. The resulting growth in industrialized pork production systems within China has boosted demand for soy meal-rich feeds (Galloway et al., 2007). More efficient animal production systems also account for higher meal use: backyard feeding ('traditional production') accounted for 95 percent of pork production in the early 1980's, but this fraction is declining (Tuan, Fang, & Cao, 2004). As specialized household operations and large-scale commercial operations take over, demand for processed animal feeds will grow. In 2010, China crushed 57.4 million metric tons of soybeans for animal feed, generating 10.5 million metric tons of soybean oil co-product. China mostly imports whole beans and then crushes them to get the meal (for livestock feed), the oil (for food consumption) and the value added. China imported 55 million metric tons of soybeans in 2011, about 62 percent of global world trade in soybeans (USDA, 2011b).

The large amount of soybean oil that is a co-product of soybean meal production reduces demand for alternate vegetable oils. China's total soybean oil consumption in 2010 was 12.1 million metric tons (mmt), of which 10.5 mmt was met by the domestic crushing industry; so, only 1.6 mmt of additional soybean oil had to be imported. The rest of China's vegetable oil consumption came from rapeseed (5.7 mmt), palm oil (5 mmt), and small amounts of peanut, cottonseed, sunflower, and coconut oils (see figure 4-6).

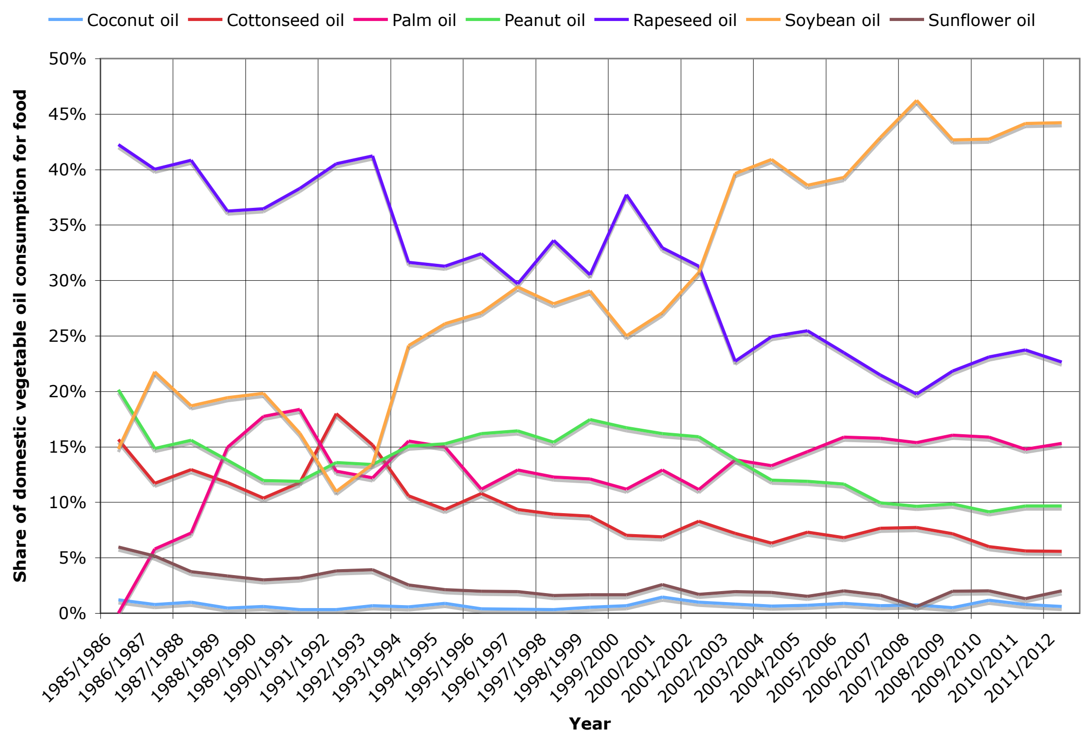

Figure 4-6. Vegetable oil substitution in China, 1965 – 2010.
Source: (USDA, 2011b)

Compared to Indonesia and India, China uses the smallest fraction of palm oil in its overall vegetable oil consumption (see regional data in table 4-5). In China, the market for soybean meal as an animal feed has put a floor on soybean oil consumption. A large amount of soybean oil is readily available, so only vegetable oil demand beyond that quantity will likely come from other crop sources. (Of course if prices were right, China could export soy oil and import palm oil.) Growth of pork production also supplies fats, which substitute for palm oil to some extent. In addition to soybeans, rapeseed is also crushed in China to produce feed for the livestock sector and cooking oil. Rapeseed's higher price in the international market, relative to soybean and palm oil, might be one reason for its declining share of Chinese vegetable oil consumption (see figure 4-6).

The link between meat consumption and the composition of China's vegetable oil diet suggests a limit on future palm oil consumption. Since the income elasticity of meat consumption is higher than the income elasticity of vegetable oil consumption, as incomes grow, soybean oil availability in China will increase faster than total vegetable oil demand[28]. If the soybean oil co-product of animal feed production is consumed domestically rather than re-exported, that means that demand for alternative vegetable oils, including palm oil, will decline.

As figure 4-6 shows, soybean oil consumption has been increasing in China (due to domestic production and soybean meal) and palm oil consumption has been increasing, while rapeseed oil and the minor vegetable oils (peanut oil, coconut oil, sunflower seed oil, and cottonseed oil) are declining in relative importance. Rapeseed oil and other oils besides soybean oil are gradually being replaced by palm oil in Chinese diets.

The predictions in table 4-12 assume that soybean oil continues to grow its share of Chinese vegetable oil consumption while palm oil replaces most of the other minor vegetable oils due to its lower price. As shown in table 4-9, income growth is assumed to remain high (6%), but the effect of higher incomes will be tempered by a low average income elasticity for vegetable oil consumption of 0.1. China's population growth rate will remain low (0.23%). It is the substitution of palm oil for other minor oils in China, thus increasing palm oil's share of China's vegetable oil market, that will account for most of the growth in palm oil consumption in China.

[28] Assuming that soybeans continue to be crushed domestically

Table 4-12 Past and future palm oil consumption in China.
Source: USDA, author's calculations

	Growth rates		Levels	
	1985 – 2010	**2010-2035**	**2010**	**2035**
Consumption / capita (kg)	11.45%	2.58%	3.73	7.06
Total consumption (million tons)	12.44%	2.81%	5.0	9.9

Thus, the world's top three palm oil consuming nations, Indonesia, India, and China, have distinctly different vegetable oil consumption patterns that reflect their different domestic agricultural priorities, dietary preferences, and policy environments. As a result of the different historical evolutions of vegetable oil consumption in these three countries, their future consumption pathways for palm oil look very different. Indonesia has virtually no room to substitute further for palm oil in domestic diets; however, China (with 15% of vegetable oil consumption from palm oil) and India (with 35% of vegetable oil consumption from palm oil) have more potential to substitute towards palm oil. Of these two countries, palm oil consumption growth is likely to be faster in India due to population growth and because China's livestock sector will favor vegetable oils (like soybean oil) that also have a meal component.

Global projections

Forecasting global palm oil consumption growth requires grand assumptions not just about what will happen to population and incomes, but also about what will happen to dietary patterns for vegetable oils around the world. New markets for palm oil will no doubt emerge outside of Asia. While Asia has been responsible for most of the world's palm oil consumption growth over the past twenty-five years, in the next twenty-five years, Africa could begin to catch up in importance. Population and income growth in parts of Africa, aided by growth in domestic palm oil production, are likely to cause big increases in palm oil consumption. Oil palm is highly suitable to the climate in West Africa; indeed, this is where the species is native. Nigeria is currently the world's fifth largest palm oil producing country; Cote d'Ivoire is number eight.

Recent population projections from the United Nations project that Africa's population will increase by 600 million people between 2010 and 2035. In contrast, Europe's population will grow by 17 million and Asia's population will grow by 800 million (United Nations, Department of Economic and Social Affairs, 2011). High rates of population growth, income growth, and existing taste preferences for palm oil (see table 4-13) could add up to a sizeable new market for palm oil (see table 4-14). Palm oil already accounts for 50 percent of African vegetable oil consumption, and this share is growing (see figure 4-7).

Table 4-13 Regional vegetable oil consumption patterns in sub-Saharan Africa
Source: World Bank, USDA

	Vegetable oil consumption (kg/cap)	Palm oil consumption (kg/cap)	Percent from palm oil
West Africa	7.9	4.8	61%
Central Africa	6.0	4.2	71%
East Africa	5.6	4.6	82%
South Africa	6.8	3.4	49%

Table 4-14 Estimate of African palm oil consumption in 2035 and underlying assumptions.
Source: World Bank, USDA

Africa	2010-2035
Population growth	2.08%
Income growth per capita	2.3%
Income elasticity	0.2
Price growth	0%
End-of-period share	65%
Share growth	1.05%
2010 palm oil consumption (kg/cap)	5.10
2010 palm oil consumption (tonnes)	5,120,000
2035 palm oil consumption (kg/cap)	**7.42**
2035 palm oil consumption (tonnes)	**12,455,000**

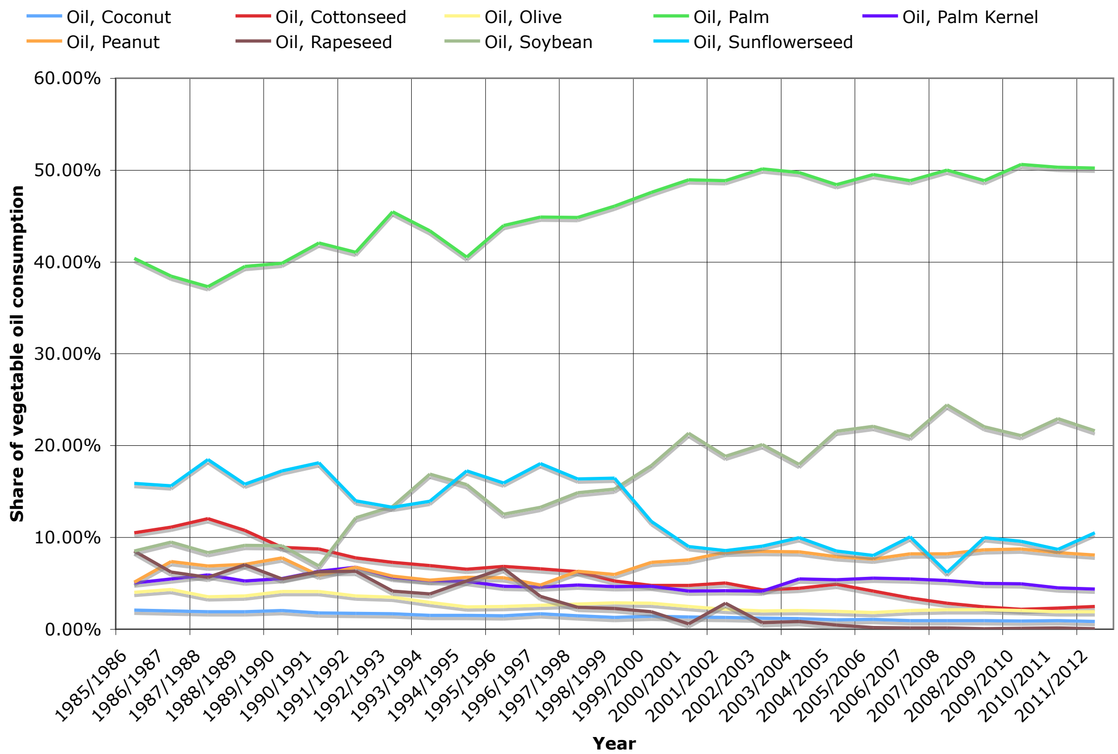

Figure 4-7. Vegetable oil consumption shares in Africa, 1985 - 2012.
Source: USDA

For the world as a whole, per capita income growth rates are predicted to rise, while population growth rates will decline slightly. Palm oil's share of the world vegetable oils market is expected to grow due to changes in Asia but also due to new growth in vegetable oils demand that is favorable towards palm. Rough parameter estimates for the world in the next twenty-five years are presented in table 4-15, along with reference values for the period 1985 – 2010.

Table 4-15 Projection assumptions and previous-period averages, World. Author's estimates are shown in blue. Sources: World Bank, USDA

	1985-2010	**2010-2035**
Population growth	0.96%	0.93%
Income growth per capita	0.96%	2.00%
Income elasticity	0.3	0.1
Price growth	-1.40%	0%
Price elasticity	-0.5	-0.3
End-of-period share	31.27%	50%
Share growth	2.07%	1.90%

Consumption predictions for the world in 2035 are shown in table 4-16. For the world as a whole, palm oil consumption will grow less than half as fast as it did in the period 1985 – 2010, despite faster-growing incomes. Slower palm oil consumption growth results from lower population growth, lower income elasticities of demand for vegetable oil as countries become more wealthy, and lower growth rates of substitution toward palm oil across the board. Yet, despite slowing growth rates, the total amount of global palm oil consumption will more than double, from 36 million tons in 2010 to 77 million tons in 2035.

Table 4-16 Past and future palm oil consumption, World.
Source: USDA, author's calculations

	Growth rates		Values	
	1985 – 2010	**2010-2035**	**2010**	**2035**
Consumption (kg/cap)	5.89%	2.10%	5.39	9.05
Total consumption (million tonnes)	7.32%	3.07%	36.5	77.7

China, India, and Indonesia will have an increasingly large role in global palm oil markets, on the demand side (see figure 4-8). As a region, Africa's share of global palm oil demand will also grow. Before palm oil became the highly-traded global commodity that it is today, palm oil was already a staple cooking oil in West-African and Central-African diets. Over the next twenty-five years, Africa could begin to re-emerge as a major market player on the demand side – and also on the supply side, as discussed in chapter 6.

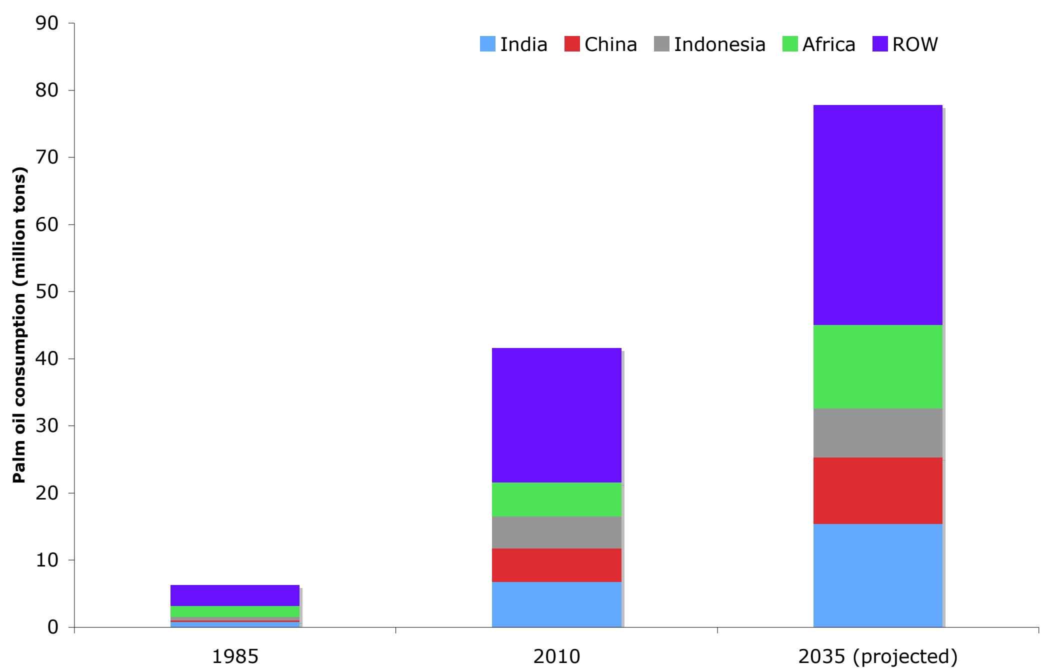

Figure 4-8. Palm oil consumption in 2035.

Model sensitivity

Global and regional palm oil consumption estimates for 2035 are, of course, highly sensitive to the embedded assumptions about income growth, price changes, and other parameters in the model. Table 4-17 demonstrates how predictions about global annual per capita consumption growth respond to price changes and a ten percent increase in each of the other relevant model variables. Per capita income growth's interaction with the income elasticity dampens the effect of a ten percent increase in this variable. In contrast, a ten percent increase in the growth of palm oil's share of vegetable oil consumption translates directly into a ten percent increase in per capita palm oil consumption growth. Changes in the price elasticity have no impact on projections when prices are assumed to be constant. With a one percent annual increase in palm oil prices, price elasticities become critical to the predictions. A one percent annual increase in palm oil prices, coupled with a global average price elasticity of -0.3, translates into global per capita consumption growth of 1.8 percent per year, compared to 2.1 percent per year in the baseline prediction. A one percent annual decrease in palm oil prices, coupled with the same price elasticity, translates into global per capita consumption growth of 2.4 percent per year. When all of the variables are increased simultaneously, palm oil consumption growth is higher than the baseline under the high price scenario (2.66%) and lower than the baseline prediction under the higher price scenario (2.10%).

This simple sensitivity analysis demonstrates that a prediction of annual per capital palm oil consumption growth on the order of two percent is generally robust. Two important lessons, however, are that (1) the share of oil palm in total vegetable oil consumption is critical and (2) large, sustained price increases for palm oil could significantly decrease the rate of demand growth. The concluding chapter of this thesis discusses some of the supply-side factors that are important to price formation. On the demand side, biodiesel production, discussed in the next chapter, could have a significant effect on prices.

Table 4-17 Annual increase in global per capita palm oil consumption, 2010-2035, under various parameter assumptions.

Parameters in the blue squares are 10% higher in absolute value than their baseline equivalents, except in the case of price growth, which changes from zero to ±1%.

	Income growth	Income elasticity	Price growth	Price elasticity	Share growth	Annual per capita palm oil consumption growth
Baseline prediction	2.00%	0.10	0.00%	-0.30	1.90%	**2.10%**
10% higher income growth	2.20%	0.10	0.00%	-0.30	1.90%	**2.12%**
10% higher income elasticity	2.00%	0.11	0.00%	-0.30	1.90%	**2.12%**
Price increase	2.00%	0.10	1.00%	-0.30	1.90%	**1.80%**
Price decrease	2.00%	0.10	-1.00%	-0.30	1.90%	**2.40%**
10% higher price elasticity	2.00%	0.10	0.00%	-0.33	1.90%	**2.10%**
10% higher 'share' growth	2.00%	0.10	0.00%	-0.30	2.09%	**2.29%**
Combined effect, price increase	2.20%	0.11	1.00%	-0.33	2.09%	**2.00%**
Combined effect, price decrease	2.20%	0.11	-1.00%	-0.33	2.09%	**2.66%**

Conclusion

The substitution properties of vegetable oils mean that supply and demand for palm oil, soybean oil, or any other oil crop are best understood by looking at global vegetable oils markets as an integrated whole. Demand growth for vegetable oils is large, and if palm oil is increasing its share of vegetable oils markets, then demand growth for palm oil will be even larger.

In China, India, and Indonesia, substitution towards palm oil has been more important than population growth in raising palm oil consumption. For Indonesia, substitution has been more important, even, than income growth. Palm oil's share of Asian vegetable oil consumption has doubled in twenty-five years, from under 20% in 1985 to almost forty percent in 2010. This share cannot grow forever -- by now, Indonesia has fully switched over to palm oil for cooking. Other Asian countries, however, still have room for further substitution. Within Asia, China currently consumes the lowest level of palm oil as a fraction of total cooking oil. Because of China's livestock industry, palm oil is likely to remain less attractive as a cooking oil in China relative to oilseeds that have a meal co-product. Substitution potential could be much higher in India.

The specifics of trade policy, domestic production, and improving diets – higher butter consumption in India and higher pork consumption in China, for example - are all important determinants of which vegetable oils the world chooses to consume and, as a result, the specific geographic pressures facing tropical forests across the globe. Pork consumption in China, while it has had a heavy impact on soybean expansion in the Brazilian Amazon, is to some degree relieving pressure on the palm oil industry and forests in Southeast Asia.

Because substitution between vegetable oils affects consumption trends so enormously in the case of palm oil, the potential growth in palm oil demand is larger than one would predict based on income and population growth, alone. Further, high rates of population growth in Africa, where palm oil accounts for fifty percent (and growing) of vegetable oil consumption, will add to the global trend of increased palm oil consumption. A doubling of global palm oil demand in the next twenty-five years seems highly likely. The enormous land-use implications of this doubling are discussed the final chapter.

Chapter 5 Effects of biodiesel on global palm oil demand

Palm oil consumption for food is growing, particularly in Asia, as a result of population growth, income growth, and substitution. As demand for edible oils grows, palm oil is filling the gap and even replacing other oils due to its lower production costs.

But, food use is only part of the story of vegetable oils demand. About a quarter of palm oil consumption goes to industrial uses such as soaps, cosmetics, and biofuels[29]. Biofuels production, in particular, is a new and highly uncertain source of palm oil demand. Over the last decade, biofuels have transformed global agricultural markets, generating higher agricultural commodity prices (Mitchell, 2008; Naylor et al., 2007; Rosegrant, Zhu, Msangi, & Sulser, 2008), higher production (Alexandratos, 2009), agricultural expansion (Fargione, Hill, Tilman, Polasky, & Hawthorne, 2008); (Hertel et al., 2010), and, perhaps most troubling, lower food consumption among the poor (IIASA, 2009; Rosegrant et al., 2008; Runge & Senauer, 2007). On the positive side, the World Bank has asserted that changes in sugar markets caused by biofuels production are one answer to Africa's agricultural development challenges (World Bank, 2009). In Mozambique, requests for land concessions for new biofuel plantations exceed the cultivated area of the country (World Bank, 2009). In Ethiopia, out-grower schemes for castor oil (a biodiesel feedstock) are raising farmer incomes (Negash & Swinnen, 2012). When the risks facing farmers are not too large, the income generation potential of crop-based biofuels is very promising (Ewing & Msangi, 2009).

Most of the criticism that the environmental community has leveled at palm oil is connected to palm oil's use not for food, but as a biodiesel source. Tremendous growth in palm oil production -- and the accompanying tropical deforestation -- has coincided with growth in global biofuels production. Is this coincidence of palm oil production growth and biodiesel expansion meaningful?

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[29] For palm oil substitutes: soybean oil, rapeseed oil, and coconut oil, the fraction of total production going to industrial uses is 18%, 32%, and 46%, respectively (see table 2-1).

Evidence suggests that the parallel rise of palm oil use and biodiesel production may be purely coincidental. Biodiesel's direct impact on palm oil demand, to date, has been small. In 2010, palm oil made up approximately 12 percent of global biodiesel production (see table 5-2); a previous estimate from 2006 put this fraction at less than 1% (Thoenes, 2006). European biodiesel consists of less than 7% palm oil feedstocks (Flach, Lieberz, Bendz, Dahlbacka, & Achilles, 2010) (see table 5-1). For edible oils in total, and for palm oil in particular, the majority of consumption goes to food demand (see figure 5-1).

Still, the future is an open question. Changes in petroleum prices or government policy could have enormous effects on palm oil demand as a fuel. As the cheapest vegetable oil, palm oil would be well poised – in a world governed by prices rather than subsidies or mandates geared at specific crops – to fuel the biodiesel industry. Or, palm oil producing countries could decide to subsidize the palm oil industry and rural economic growth through biodiesel policy, following a path similar to the United States and corn ethanol. This event could happen if supply growth starts exceeding demand growth and prices are on a downward trajectory, in real terms. This chapter examines the impact of biodiesel production on palm oil markets to date, and likely future scenarios.

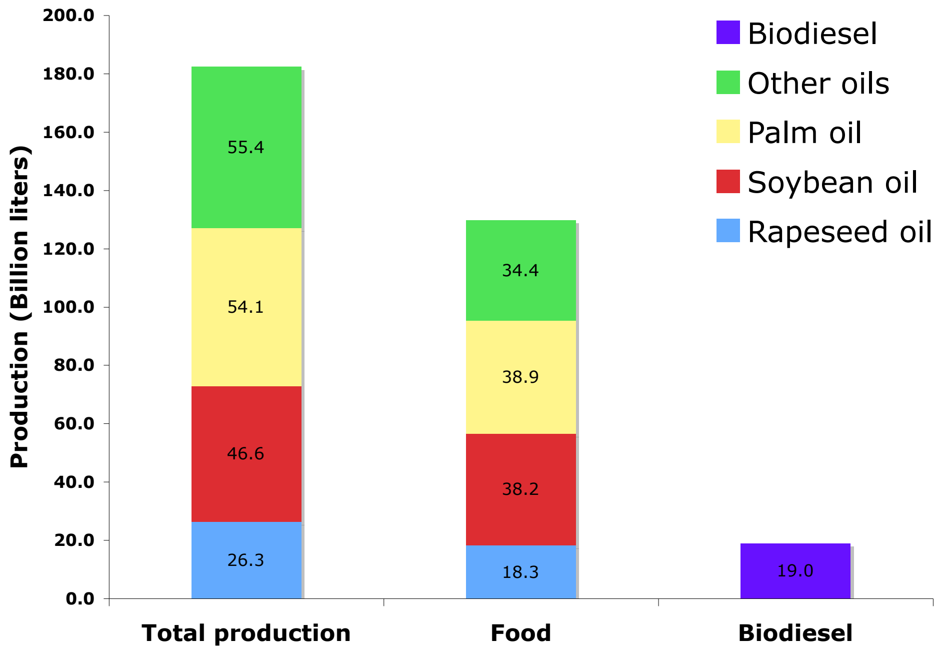

Figure 5-1. Edible oils production, food use and biodiesel production in 2010.
Source: USDA, REN21

Table 5-1 Composition of European biodiesel feedstocks.
Source: USDA FAS 2011

Feedstock used for biodiesel production (1,000 MT)

	2006	2007	2008	2009	2010	2011
Rapeseed oil	3900	4400	5140	5900	7500	7270
Soybean oil	400	700	950	770	740	750
Palm oil	120	250	530	540	660	740
Sunflower oil	10	70	170	250	250	250
Other virgin veg. oils	230	300	385	400	400	400
Recycled veg. oils	70	200	295	370	565	620
Animal fats	50	130	280	270	320	320
Other			30	35	40	40
Total	4780	6050	7780	8535	10475	10390

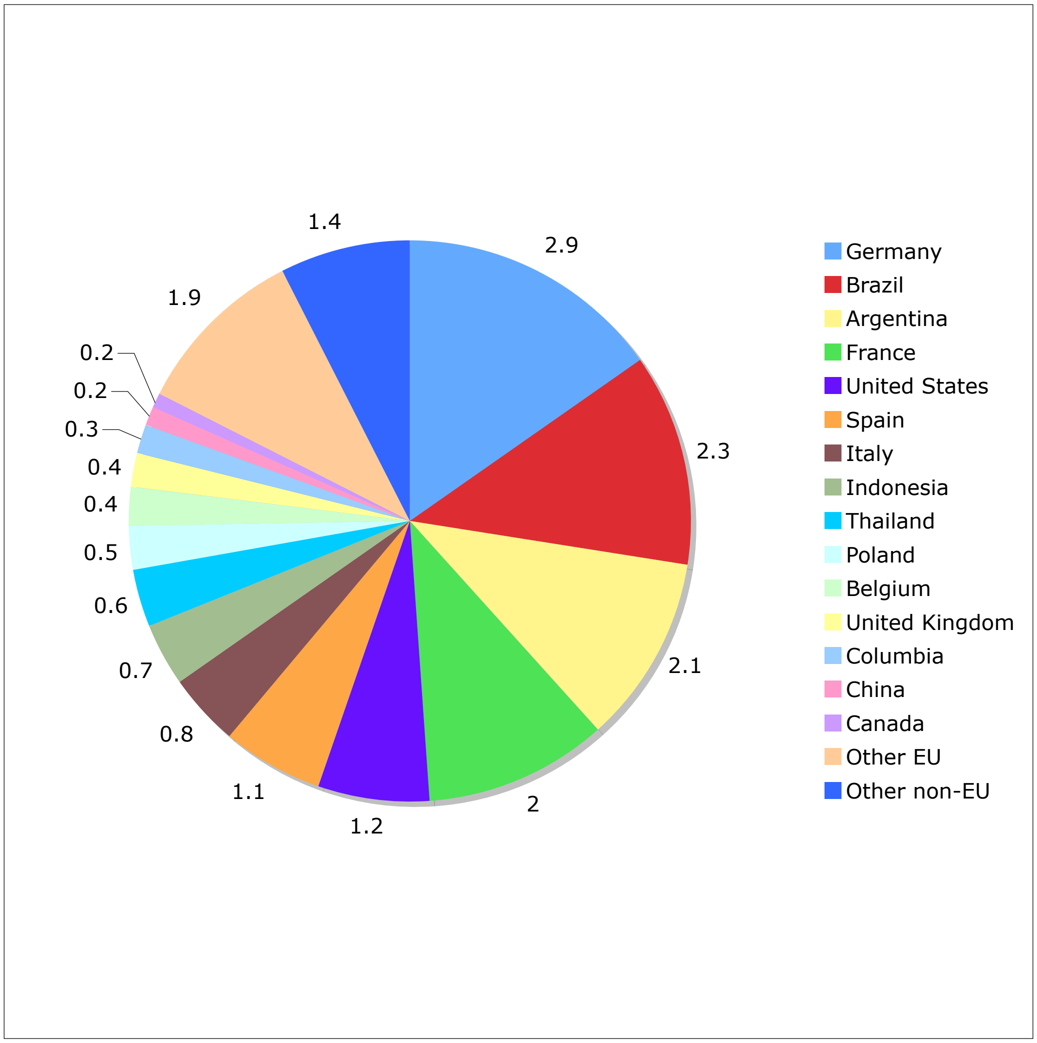

Figure 5-2. Biodiesel production in 2010, by country (billion liters).
Sources: (REN21, 2011; Worldwatch Institute, 2012)

Table 5-2 Estimated shares of vegetable oils, by type, going to biodiesel (2010).
Sources: USDA FAS, USDA PSD tables, author's estimates (non-EU countries).

	2010 Biodiesel Production (Billion liters)	Estimated Feedstock Share (%)							
		Rapeseed oil	Soybean oil	Palm oil	Sunflower oil	Other virgin vegetable oils	Recycled vegetable oils	Animal fats	Unknown
European Union	10	70%	7%	7%	2%	5%	6%	3%	-
Brazil	2.3	-	89%	4%	1%	6%	-	-	-
Argentina	2.1	-	86%	-	14%	-	-	-	-
United States	1.2	6%	88%	-	1%	5%	-	-	-
Indonesia	0.7	-	-	100%	-	-	-	-	-
Thailand	0.6	-	16%	75%	-	9%	-	-	-
Columbia	0.3	-	4%	87%	-	9%	-	-	-
China	0.2	20%	52%	10%	2%	16%	-	-	-
Canada	0.2	92%	8%	-	-	-	-	-	-
Other non-EU	1.4	-	-	-	-	-	-	-	100%
World Total	19	38%	31%	12%	3%	2%	3%	2%	7%

Current biodiesel production volumes and sources

Like ethanol, biodiesel is a liquid transportation fuel that substitutes for its petroleum-based alternative[30]. While ethanol replaces gasoline, biodiesel replaces diesel fuel in cars, trucks, and some stationary (heating or power) applications. In 2010, global biodiesel production was 19 billion liters, the majority (53%) of which was produced and consumed in the European Union (REN21, 2011)[31]. Global biodiesel production is presently equivalent to approximately one percent of global diesel consumption (EIA, 2012).

Converting the world's entire vegetable oils crop (182 billion liters in 2010, see figure 5-1) into biodiesel would still only meet 13 percent of global diesel use. Thus diesel and petroleum prices are more likely to affect vegetable oils markets than the reverse. Biodiesel's small share of the overall diesel market implies that the impact of crop-based biodiesel production on energy prices is going to be small, at least at the global scale, but not vice versa. The same is true for other biofuels.

Which crops will be most affected by biodiesel policy and changes in diesel prices that might make biodiesel production profitable? At present, biodiesel is most commonly manufactured from oil crops such as rapeseed, soy, and palm. Waste cooking oil, animal fats, and minor oils such as castor oil or jatropha are other potential feedstocks. Feedstocks differ primarily in their price, but they can produce slightly different biodiesels. The most important performance concern with biodiesel is its suitability in cold environments. Biodiesel 'clouds' at a lower temperature than petroleum diesel, meaning that, at low temperatures, biodiesel forms wax crystals that can clog a vehicle's fuel system (Radich, 1998). "Cloud points" and "pour points[32]" differ for biodiesel made from different feedstocks. Palm-based biodiesel has an even higher cloud point and pour point than rapeseed or soybean diesel, making biodiesel made

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[30] Biodiesel can be blended with petroleum diesel in any ratio, but above 30%, biodiesel can dissolve the rubber seals in car engines, which must be replaced with non-rubber alternatives.
[31] For comparison, 2010 global ethanol production was 86 billion liters (REN21, 2011).
[32] The temperature at which fuel becomes too viscous to travel through the engine.

from palm oil even less effective during winter months in parts of the US or Europe. Solutions to this problem include special engine heaters, chemical additives, or blending with other biodiesels.

The current composition of global biodiesel production is uncertain. Table 5-2 presents feedstock estimates for Europe, from the USDA. A good approximation of the relative contribution of different vegetable oils to global biodiesel production can be obtained by combining: (i) data on national biodiesel production (see figure 5-2) and (ii) reasonable assumptions about the most likely vegetable oil feedstocks for biodiesel, by country, based on national policies and crop production patterns. Table 5-2 shows the results of this analysis. Estimates about feedstock use for biodiesel by country were based on vegetable oil production shares in each country, with two exceptions: Biodiesel feedstock shares for Europe are taken from a prior estimate (USDA FAS 2011), and biodiesel feedstock shares for China account for the vast difference between production and consumption trends. Some Chinese biodiesel production is estimated to come from palm oil - even though no palm oil is produced in China - since palm oil represents a significant fraction of Chinese vegetable oil consumption. The global biodiesel feedstock shares as estimated in table 5-2 assume that biodiesel trade between countries is minimal.

Production costs

Converting vegetable oil into biodiesel is a relatively simple, low-cost process[33]. While vegetable oils can be combusted directly in diesel engines, unaltered cooking oil is less volatile and therefore ignites less easily in engines than biodiesel. To convert vegetable oils into biodiesel, a common chemical process is to react the vegetable oil with methanol in the presence of sodium hydroxide to produce methyl esters (biodiesel) and glycerol.

[33] Indeed, students once created a biodiesel manufacturing "plant" in Mitchell basement at Stanford.

Most of the costs associated with producing biodiesel are the feedstock costs. Excluding feedstock input costs and energy input costs, the variable costs of producing biodiesel are around \$0.31-\$0.33[34] per gallon (Liwang, 2007; Radich, 1998). Glycerol, a byproduct of the chemical manufacturing process, might reduce net costs by around \$0.15 per gallon (Radich, 1998), but the glycerol market is sensitive to volumes, so the value of this co-product may disappear at large production scales.

Since there is currently excess global capacity for producing biodiesel, fixed costs generally do not factor into most biodiesel production decisions at present. Table 5-1 details the excess biodiesel capacity in several regions. Malaysia uses only 9 percent of its existing capacity to produce biodiesel; Europe uses only 45 percent.

Table 5-3 Excess biodiesel production capacity by region.
Sources: (National Biodiesel Board, 2009; (Chin, 2011; Flach et al., 2010; Slette & Wiyono, 2011)

	Total Production (Billion liters)	Total Capacity (Billion liters)	Capacity Utilization
European Union	11.6	26	45%
United States	2.1	10.2	20%
Indonesia	0.455	3.9	12%
Malaysia	0.26	2.9	9%

Fixed costs could play a larger role in the future if biodiesel production were to become more profitable. Under this scenario, additional biodiesel capacity could become available from oleochemical producers who are currently using methyl esters to produce soaps, detergents, or other higher value commodities. In the US, a new, large-scale biodiesel plant costs in the range of \$1.00 - \$1.60 per gallon of capacity (Mitchell, 2011; Radich, 1998). Assuming full capacity over 15 years with ten percent returns, this translates into a capital cost of at least \$0.13 per gallon. Adding this annualized fixed cost to the variable costs[35] raises the current cost of converting vegetable oil into biodiesel to around \$0.45 per gallon.

[34] Unless otherwise specified, costs are in 2005 US dollars.
[35] Ignoring energy costs and the value of glycerol.

Price environment

Whether it is profitable to produce biodiesel depends primarily on the relative prices of diesel and vegetable oil feedstocks. Both diesel and palm oil prices have been rising over the last decade, as evidenced in figure 5-3. The two price series seem largely to move together, with the large exception of the food price crisis in 2008 when palm oil prices shot up, leaving diesel prices behind. In the figure, periods where the red line (CPO prices) is below the blue line (diesel prices) indicate potential profitable periods for producing biodiesel.

In looking at relative diesel and palm oil prices, however, it is important to consider the fact that in terms of thermal units, biodiesel contains only 89%, by volume, of the energy content of petroleum diesel (Miroslava, Drabik, & Ciaian, 2011; Radich, 1998). Further, as discussed previously, the variable costs of producing biodiesel are around $0.32 per gallon on top of the cost of the palm oil (or other vegetable oil) feedstock.

To date, producing biodiesel has rarely been profitable without subsidies. Figure 5-4 plots monthly palm oil and diesel prices on perpendicular axes to highlight profitable monthly periods since 2000. The straight lines represent "zero profit," where variable costs are equal to revenues under different assumptions. Ignoring conversion costs, i.e. assuming that palm oil is the only input into biodiesel, and accounting for the energy difference between palm oil and diesel, produces the blue line in the middle. The majority of palm oil price points (black dots) are above this line, but the graph shows that with zero conversion costs, biodiesel production from palm oil has sometimes been profitable. Factoring in average variable conversion costs of $0.32 per gallon changes the equation, producing the green line. Palm oil prices have rarely been low enough to make biodiesel profitable under this scenario. Finally, the purple line represents zero profit with a $1.00 per gallon subsidy, equivalent to the blending credit that existed up until 2011 in the United States. With this subsidy, biodiesel production is profitable with a much higher frequency. Only a few high, outlying monthly palm oil prices fall above the purple line. The former US blending tax credit was a powerful, game-changing incentive to produce biofuels.

Adding in the prices for rapeseed oil and soybean oil over the same ten-year period illustrates the cost advantages of palm oil as a biodiesel source, relative to other edible oils (see figure 5-5). Both alternative oils require larger subsidies to make biodiesel production profitable. Over the past ten years, rapeseed- and soybean-based biodiesel has not been profitable without subsidies (mandates or subsidies are necessary to encourage production), whereas biodiesel made from palm oil occasionally has been profitable without subsidies.

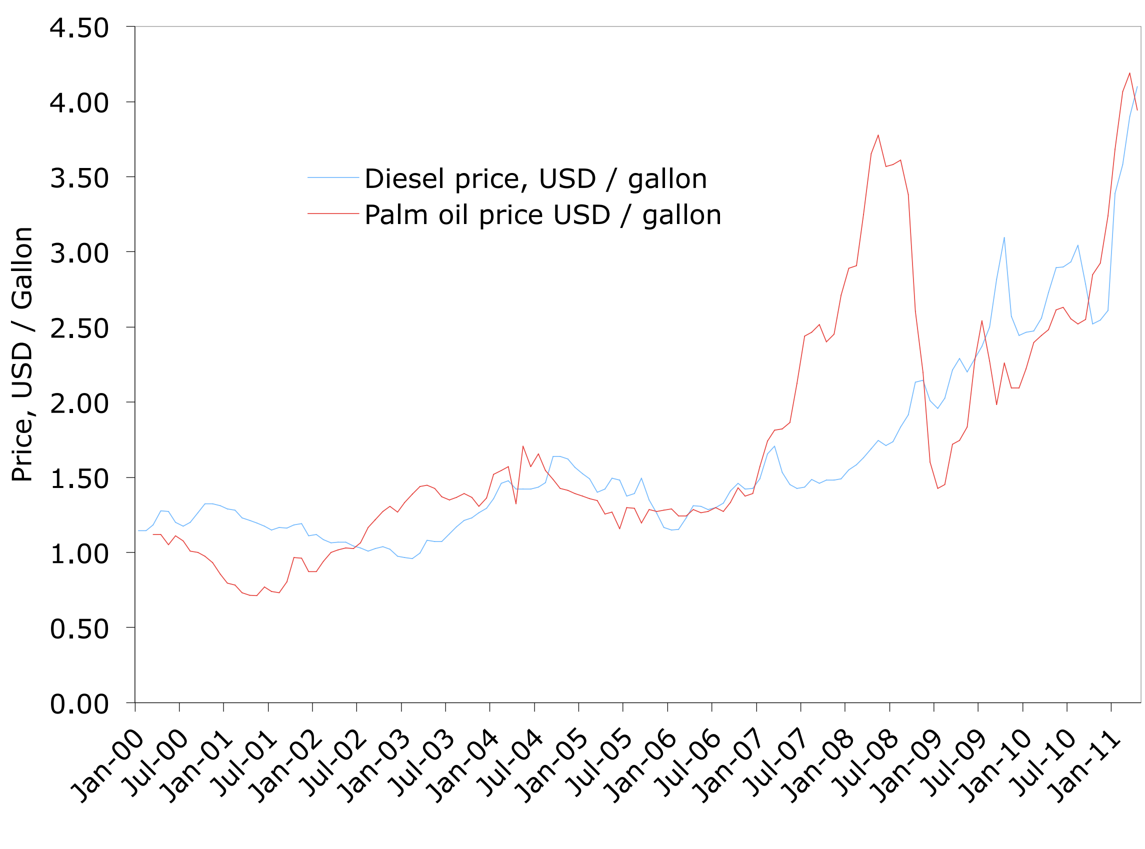

Figure 5-3. Crude palm oil and diesel prices, 2000-2010.
Nominal price data from EIA, GFD.

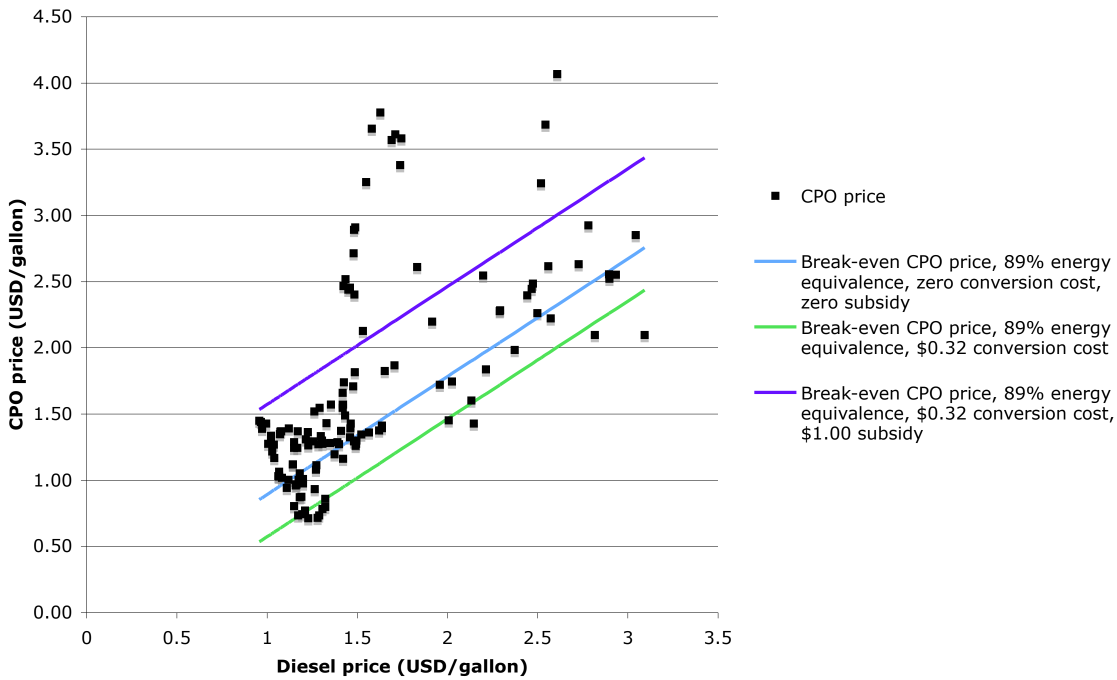

Figure 5-4. Historical crude palm oil (CPO) prices and biodiesel profitability, 2000 – 2010 (monthly data).

Palm oil prices that fall below the solid green line indicate months when biodiesel production was profitable, without subsidies, given the coincident diesel price. Sources: GFT, IEA.

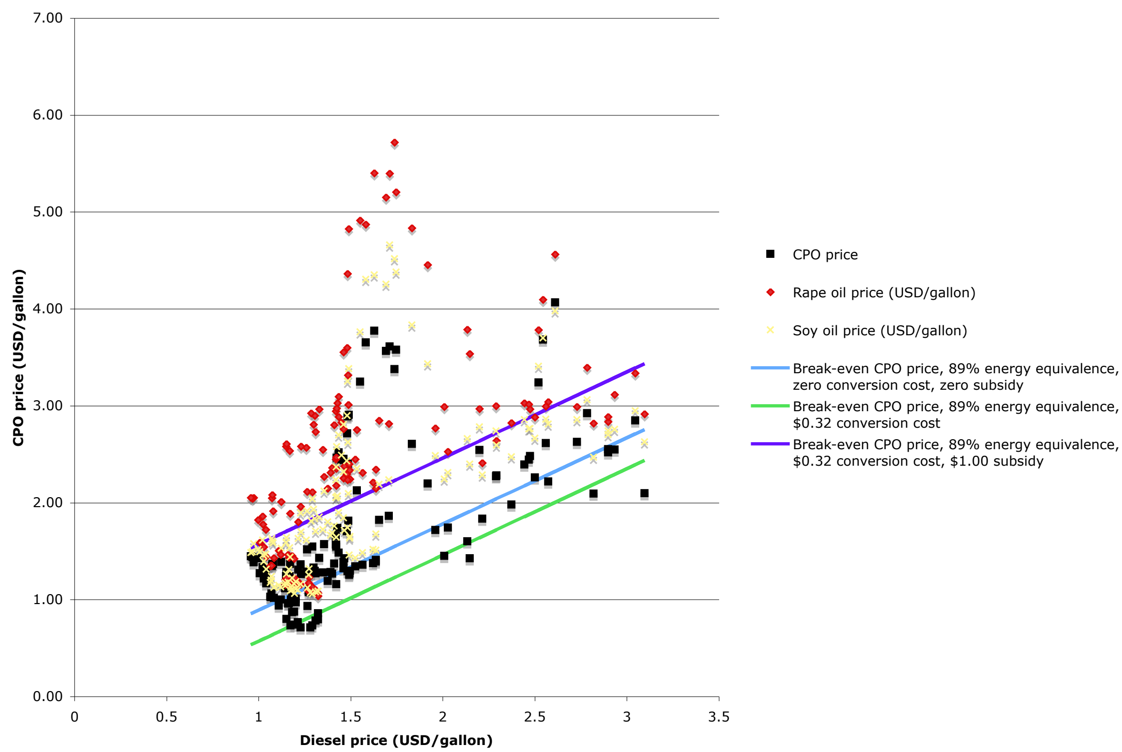

Figure 5-5. Profitability of biodiesel production from three different vegetable oil feedstocks.
Over the past ten years, rapeseed- and soybean-based biodiesels have not been profitable without subsidies, whereas biodiesel made from palm oil occasionally has.

Graphical interpretation: Elastic demand when biodiesel is profitable

When it is profitable to produce biodiesel from palm oil, i.e. when palm oil prices fall below the relevant diesel price as expressed in figures 5-4 and 5-5, then biodiesel producers will have an economic incentive to buy up palm oil and turn it into transportation fuel. Because the market for diesel fuel is so large, relative to the market for palm oil (or vegetable oils), extra biodiesel production will hardly affect the price of diesel. Demand for palm oil for biodiesel will affect the palm oil price, raising the palm oil price to a level, P_B, where biodiesel production is profitable and economic profits in the biodiesel industry are zero. Palm oil demand, at this price, will be virtually infinite. Graphically, this phenomenon can be expressed as a flattening of the demand curve for palm oil at the price level, P_B (see figure 5-6). In figure 5-6, palm oil supply is assumed to be relatively elastic (productive land, labor, and higher quality planting material are available to producers). Demand for palm oil is downward sloping initially, reflecting higher food demand for palm oil at lower price points, before demand becomes suddenly more elastic when biodiesel production is profitable[36]. Depending on the cost of converting palm oil (or another oil) into biodiesel, and depending on the cost of diesel, palm oil's demand curve will flatten out at different price points (see figure 5-6).

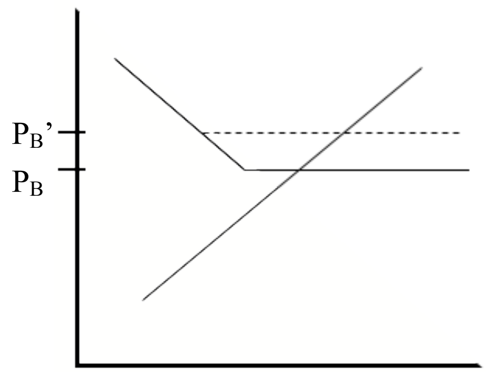

Figure 5-6. Price of palm oil at two different diesel price points.
The demand schedule for palm oil changes with diesel prices.

If palm oil prices are such that biodiesel production is not profitable, then diesel prices do not determine palm oil prices and palm oil demand. Instead, the shape of the demand schedule is governed by the price elasticity of food demand. This situation is depicted in figure 5-7. In this case, a higher diesel price has no effect on palm oil prices or demand (assuming no shifts to the supply curve from higher input costs) because palm oil is not being used to produce biodiesel. In this case, where no palm oil is being used to produce biodiesel, food demand pulls the palm oil price above the upper limits of the price "corridor" that would otherwise moderate palm oil's price (Schmidhuber, 2008).

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[36] Profitability, as defined in equation 3, is when palm oil's price plus a conversion cost is lower than the price of diesel fuel, making the price-dependent component of biodiesel production positive.

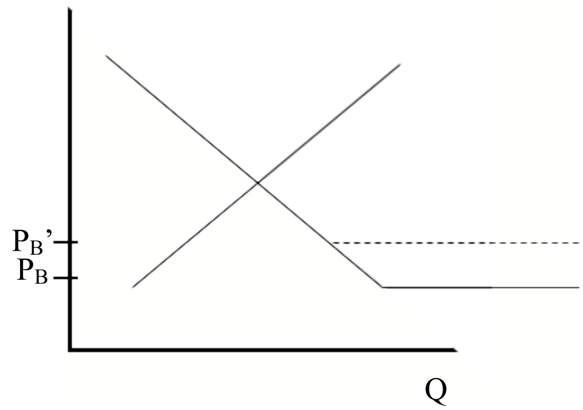

Figure 5-7. Palm oil prices when biodiesel production is unprofitable.
Palm oil prices do not respond to changing diesel prices when biodiesel production is unprofitable.

Empirical price linkages

Which scenario is presently the more realistic one? Are changes in diesel prices correlated with changes in the price of palm oil, or are palm oil prices determined instead by supply factors and food demand? As seen in figures 5-4 and 5-5, there have not been many historical periods when biodiesel production has been profitable, so there are not very many data periods to go on to measure how changes in diesel prices and biodiesel profitability are transmitted to vegetable oils markets.

In some cases since the year 2000, palm oil price formation may have been driven by diesel prices (see table 5-4). Statistical analysis of global diesel and palm oil prices suggests that palm and diesel prices moved together in months when biodiesel production was profitable (see table 5-4). 'Profitability' is defined as those months where the price of palm oil was less than or equal to the price of diesel oil, minus the conversion cost; i.e. when the endogenous, price-dependent component of biodiesel demand is positive. Table 5-4 shows results for three different conversion costs: a zero cost scenario, 33 cents, and a high cost, 45 cents scenario. In all three cases, the correlation between vegetable oil prices and diesel prices is high in months when biodiesel production is profitable and low in months when biodiesel production is not profitable. Further, the correlation between palm and diesel prices becomes stronger when biodiesel production is more profitable (as measured by the price difference between diesel and palm oil). A higher conversion cost / profitability threshold leads to higher correlation between palm and diesel prices when biodiesel is profitable. Adding one and two month time lags to the correlation analysis (to account for delays before biodiesel producers fully enter the market in response to high diesel prices) does not increase the correlation coefficient (data not shown).

Table 5-4 Pearson coefficients showing the correlation between palm oil and diesel oil prices between 2000 and 2010.
Palm oil and diesel oil show higher correlation in months when palm oil is cheaper, relative to diesel oil. Data sources: GFD, EIA

Conversion cost	**P coefficient, "profitable"**	**P coefficient, "not profitable"**
0 cents	0.94	0.72
33 cents	0.98	0.68
45 cents	0.99	0.67

These crude correlations between palm oil and diesel prices are at best suggestive. There simply have not been enough historical periods when biodiesel production was profitable to do a satisfactory empirical analysis. In the future, with continuing uncertainty in the Middle East, movements in crude oil prices could alter price relationships. To date, the most important factor driving biodiesel production has been government subsides and mandates.

Policy environment

As a 'clean, green, renewable' fuel, biodiesel receives direct subsidies and tax credits in many producing countries. Worldwide, 31 countries currently have biodiesel mandates including: Mozambique, Ethiopia, Thailand, the Philippines, India, China, Brazil, and Argentina (REN21, 2011) (see table 5-5). When these policies are enforced, they are influential. The biggest producing countries are also those that have the most aggressive government policies.

In the European Union, all member states face a 10 percent mandated target on renewable energy consumed in transport. Currently, biodiesel comprises 80 percent of this target, with ethanol making up the remaining 20 percent (Flach et al., 2010). The most important policy leading to higher biodiesel consumption is a tax exemption at the pump, which varies by member country. In Germany in 2009, for example, this exemption was equal to 0.29 Euro / liter, or 36 percent of the selling price (De Gorter, Drabik, & Just, 2011). Importantly for palm oil, biodiesel tax exemptions do not apply equally to all biodiesels: the EU has ruled that palm-based biodiesel is not sufficiently 'sustainable' to qualify towards the EU's 10 percent target[37] and associated tax credits, even when mixed with other types of biodiesel. Soybean biodiesel, also, does not by default meet the EU Renewable Energy Directive's criteria of 35 percent greenhouse gas savings, although soybean biodiesel is permitted on a case-by-case basis (see table 5-5) (Flach et al., 2010). Despite the fact that palm biodiesel does not automatically meet the EU Renewable Energy Directive's criteria, nevertheless, 7 percent of European biodiesel comes from palm oil (see table 5-1). This 7 percent fraction could be a function of pre-existing contracts, special exemptions, imports that are not designed to fulfill the Renewable Energy Directive targets, or a combination of these three factors. Imported biodiesel faces a 6.5 percent ad valorem tax (Mitchell, 2011). Europe currently imports biodiesel from the United States, Argentina[38], Canada, Indonesia, and Malaysia (Flach et al., 2010).

In the US, soybean biodiesel receives commodity credit payments from the USDA equal to approximately $1.10 per gallon. Blending tax credits equal to $1.00 per gallon expired at the end of 2011 (De Gorter et al., 2011; Radich, 1998). As in the EU, palm-based biodiesel does not meet the US standard for 'renewable fuel' and thus does not qualify for preferential treatment (Environmental Protection Agency, 2012). The majority of US biodiesel production comes from soybean oil. Imported biodiesel faces a 1.9 percent import duty (Mitchell, 2011).

[37] Specifically, 'renewable fuels' in the EU must reduce greenhouse gas emissions by at least 35% and must not come from feedstocks grown on biodiverse lands. These standards are stricter than those imposed by the Roundtable on Sustainable Palm Oil. In the United States, the threshold to qualify as a first generation renewable fuel is 20% greenhouse gas savings.
[38] Export taxes for biodiesel are lower than export taxes for soybeans or soybean oil in Argentina.

In 2011, Indonesian biodiesel received subsidies equal to IDR 2,500 – 3,000 ($0.27-$0.33) per liter, an increase over the 2010 level of IDR 2,000 ($0.22) per liter (Slette & Wiyono, 2011). Since total feedstock costs are approximately 5,000 IDR, this is a sizeable subsidy from the perspective of biodiesel production[39]. Indonesia's sole biodiesel distributor is Pertamina, the national oil company, which blends biodiesel with diesel to make B5[40]. Diesel oil fuels 35 percent of Indonesia's transport sector. In 2010, diesel consumption was 13 billion liters, which at a 5 percent blending rate would require 643 million liters of biodiesel. In practice, 2010 biodiesel consumption was 223 million liters, suggesting laxness in blending enforcement. Simultaneously, Indonesia exported 235 million liters of biodiesel in 2010, mostly to EU countries (Flach et al., 2010).

In contrast, Malaysia has no direct subsidies for biodiesel production or consumption (Lopez & Laan, 2008), and very little production. In 2006, the country adopted a National Biofuel Policy that pledged 6 million tonnes of CPO to biodiesel production and tentatively proposed a country-wide B5 blending mandate. At the time, biodiesel production from palm oil was privately profitable without subsidies and had been for about three years, giving investors time to build infrastructure and mobilize political support (see figure 5-5). Malaysia's first commercial-scale biodiesel plant opened in Johor in 2006 (Chin, 2011). Subsequently, however, rising CPO prices made biodiesel more expensive than regular diesel. In the current price environment, Malaysia has not decided who should bear the costs of implementing a mandate – petroleum producers, blenders, consumers, or palm oil producers (who could receive a higher price selling CPO to other uses). Thus, Malaysia's B5 legislation is delayed, although a soft target remains in place. The Malaysian Palm Oil Board provides a small amount of technical assistance to the industry, for example by helping to develop winter-grade palm biodiesel technology. On the whole, biodiesel policy in Malaysia has proven to be endogenous to palm oil prices: mandate legislation that had

[39] The subsidy is small relative to Indonesia's total fuel subsidies.
[40] B5 is a mixture of 5 percent biodiesel and 95 percent regular diesel

been drafted when the economics of biodiesel production looked favorable was withdrawn when palm oil prices became too high.

Table 5-5 Biodiesel policy environments in twelve countries.
Source: Sheil et. al 2009, p. 17.

Country/ Region	Target†	Tentative or implemented?	Mandate or subsidy/tax?	Veg oil trade status	Crude mineral oil trade status
Brazil	Mandatory B2 in 2008 to B5 by 2013	Implemented	Strong tax incentives, mandate	Exporter of soya	Importer
Canada	B2 by 2012	Indicative	None	Exporter of rapeseed	Exporter
China	15% biofuels by 2020	No concrete policy	Tax support proposed	Importer of soya and palm	Importer
EU	B2 to B5.75 by 2010; Mandatory B10 by 2020	Implemented	Subsidies and tax incentives ëvoluntary mandateí	Importer of soya	Importer
India		Preparing legislation; Jatropha focus		Importer of palm	Importer
Indonesia	B2 to mandatory B5 by 2010	Tentative		Exporter of palm	Importer
Japan	B5 in 2009	Preparing legislation		Importer of soya, rapeseed and palm	Importer
Korea	Mandatory B5	Implemented	Mandate	Importer of soya and palm	Importer
Malaysia	B5	Tentative		Exporter of palm	Exporter
The Philippines	Mandatory B1 in 2007 to B2 by 2009			Exporter of coconut, importer of palm	Importer
Thailand	Indicative B5 Mandatory B10 by 2012	Implemented	Tax waiver, future mandate	Importer of soya, exporter of palm	Importer
USA	28.4 thousand million litres by 2012 (not fuel specific) General support for larger mandates	Implemented: Energy Act of 2005	Tax credits; mandatory in some states	Exporter of soya	Importer

† B2 = 2% of biodiesel mix, B5 = 5%, etc.
Source: IPOC (2007)

Table 5-6 GHG savings for different biodiesels according to EU and US regulatory agencies.
To qualify for subsidies, biodiesel must have 35% GHG savings in Europe and 20% GHG savings in USA. Green indicates that a biodiesel automatically meets the stated target. Red indicates that producers must make a special case. Sources: Flach et al. 2010, US EPA 2012.

Biodiesel type	% GHG savings, EU Renewable Energy Directive	% GHG savings, US Environmental Protection Agency
Rapeseed oil	38%	50%[41]
Palm oil	19%	17%[42]
Palm oil with methane capture at the mill	56%	17%[43]
Soybean oil from Brazil	31%	57%[44]
Soybean oil from USA	Not determined	57%[45]

Graphical interpretation: Inelastic demand with biodiesel mandates

Under the scenario when biodiesel production is unprofitable based on market prices, mandates may result in an exogenous level of demand for palm oil (to produce biodiesel) that is disconnected from diesel prices, yet which affects palm oil demand. These effects can be shown graphically by extending the earlier charts (see figures 5-6, 5-7) to include policy distortions. Palm oil's demand curve in the case of mandates would be perfectly inelastic up to the quantity, Q, set by a quota (see figure 5-8). If these (enforced) mandates are sufficiently large, they could raise vegetable oil prices in an international context. For example, if a quota, Q_m, were to drive up soybean oil demand in the United States, this quota would induce both a higher global production quantity and a higher global price for soybean oil. Higher soybean oil prices, in turn, would expand demand for palm oil, which substitutes for soybean oil.

41 (Environmental Protection Agency, 2010)
42 (Environmental Protection Agency, 2012)
43 Not considered separately from other palm oil biodiesels
44 Not considered separately from other soybean oil biodiesels
45 (Kotrba, 2010)

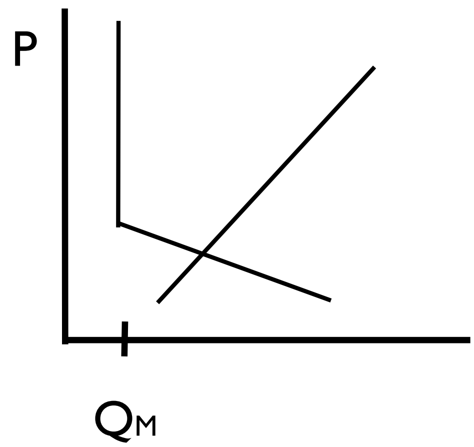

Figure 5-8. Palm oil demand with a biodiesel quota.

Palm oil's price (assuming a fixed supply schedule) is determined either by diesel prices or by a quota, but not by both at the same time. Putting all three cases together gives a demand function that is inelastic, then moderately elastic, then elastic at the price point where biodiesel is profitable. Mandates shape the top part of the curve, while petroleum prices affect the shape of the bottom end of the curve (see figure 5-9).

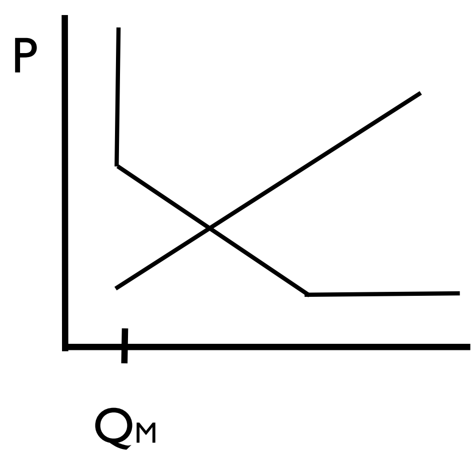

Figure 5-9. Biodiesel makes the demand schedule for palm oil both more inelastic and more elastic.

To summarize, total demand for palm oil in an era of biodiesel is thus the sum of four different components: Food demand, industrial demand (for soap, etc.) biodiesel mandates, and price-competitive biodiesel production.

Percent changes in palm oil demand for food uses (recall chapter 3) can be summarized in the equation:

(1) $$q^d_{CPO,Food} = \varepsilon_{CPO,Food} p_{CPO} + \eta_{CPO,Food} y + \Delta^{Pop} + \Delta^{Substitution} + \Delta^{Urban} + \sum_i \varepsilon_{i,food} p_i .$$

Lower case letters represent percent changes, while 'Δ' is used for variables that shift the demand curve. The right hand side variables are: the price elasticity of palm oil demand for food ($\varepsilon_{CPO,Food}$) multiplied by the percent change in palm oil price (p_{CPO}); the income elasticity of palm oil demand for food ($\eta_{CPO,Food}$) multiplied by the percent change in per capita income (y); shifts due to population (Δ^{Pop}), substitution trends ($\Delta^{Substitution}$), and urbanization (Δ^{Urban}); and the sum of cross price elasticities of demand for other vegetable oils multiplied by the percent changes in those vegetable oil prices ($\sum_i \varepsilon_{i,food} p_i$).

Non-biodiesel, industrial demand for palm oil is simply a factor of population, incomes, and prices:

(2) $$q^d_{CPO,Industrial} = \varepsilon_{CPO,Industrial} p_{CPO} + \eta_{CPO,Industrial} y + \Delta^{Pop} + \sum \varepsilon_{i,industrial} p_i$$

Whereas the income elasticity of palm oil consumption for food approaches zero at high income levels, the income elasticity of palm oil consumption for industrial purposes stays relatively high as incomes rise. As with food consumption, cross price elasticities between palm oil and other vegetable oils are high for industrial demand, somewhere on the order of 0.2 – 0.8 (Srinivasan, 2005).

Direct demand for palm oil to make biodiesel depends on the relationship between crude palm oil and diesel oil prices. In simplest terms, the price of crude palm oil plus processing costs minus any subsidies has to be less than or equal to the price of diesel oil in order for firms to have an economic incentive to produce palm oil. If mandates are enforced, then the quantity of vegetable oil needed to fulfill any mandates is additional. The following equation summarizes these relationships[46]:

$$(3) \qquad Q^{d}_{CPO,Biodiesel} = \begin{cases} Q_M & if\ (P_{Diesel} - P_{CPO} - X) < 0 \\ f(P_{Diesel} - P_{CPO} - X) & if\ (P_{Diesel} - P_{CPO} - X) \leq 0 \end{cases}$$

P_{Diesel} and P_{CPO} are the prices of petroleum diesel and crude palm oil, respectively; X is the variable production cost of making biodiesel from the input vegetable oil; S is the value of any production subsidies; and Q_M is the quantity of vegetable oil needed to fulfill any enforced biodiesel mandates. If the value of $(P_{Diesel} - P_{CPO} - X + S)$ is positive, then the variable costs of producing biodiesel are less than the cost of petroleum diesel. As long as this relationship holds, demand for palm oil to make biodiesel would be virtually infinite. Eventually, growing palm oil demand would drive up palm oil's price to the point where palm oil was no longer profitable as a biodiesel input. Given the relative abundance of tropical land for agriculture and the enormous potential for further yield increases, palm oil output could grow substantially at its existing cost[47]. Palm oil's supply curve is relatively elastic.

Future scenarios and dynamics

What would happen to palm oil prices, food security, and production if petroleum-based diesel prices were to rise substantially? Could a crisis in the Middle East reduce cooking oil consumption and increase palm oil production? Does it matter whether a subsidy is in place, or how much palm oil is going to biodiesel?

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[46] Hertel and Beckman have developed a partial equilibrium model in the context of ethanol and corn prices that is also useful for understanding how diesel prices and biodiesel production affect palm oil demand (Beckman, Hertel, Taheripour, & Tyner, 2011; Hertel & Beckman, 2011). In their model, higher diesel prices will boost palm oil prices, except in the rare case where the elasticity of fuel consumption dominates the substitution elasticity between biodiesel and regular diesel; i.e., when the reduced blending requirements from lower diesel consumption at the higher price point overcome any relative price advantages that biodiesel might gain. The increase in palm oil (feedstock) prices will be higher if: (i) supply and demand for palm oil is inelastic (ii) there is a larger share, β, of palm oil going to biodiesel, or (iii) palm oil makes up a smaller share of biodiesel production costs, θ.

[47] The largest barrier to higher palm oil production is perhaps labor shortages. Wage rates in tropical countries with suitable terrain will affect palm oil prices.

Future petroleum (and diesel) prices are notoriously difficult to estimate. The best range of estimates comes from the EIA who predict oil prices in the range of 50 – 200 dollars per barrel in 2035 based on different scenario assumptions (see figure 5-10). The reference case price for diesel fuel is 3.90 $/gallon (in 2009 dollars) in 2035 – the extreme high end of prices over the last ten years.

Assuming that biodiesel production will be small in relation to diesel production (and thus not lower the price of petroleum-based diesel), EIA oil price projections imply that vegetable oils prices will be at least as high as between $2.57 (low price scenario) and $2.66 (high price scenario) per gallon. These prices are on the low end of the historical range for rapeseed oil and not outside the historical range (not extreme) for palm oil. Looking at the EIA projections does not suggest a major change in biodiesel profitability (or the structure of vegetable oil demand) in the future.

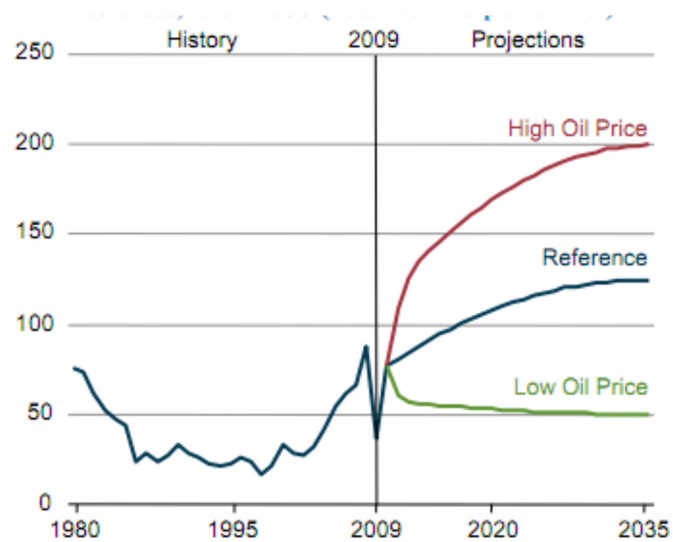

Figure 5-10. Oil price projections to 2035, three cases.
Source: EIA (2011) page 23

But, what if… In the event of a large jump in diesel prices, palm oil production would no doubt lag. Then, expectations come into play: will diesel prices stay high for four years, long enough to recoup the investment? Or will other fuels, such as those based on natural gas, enter the market, bringing diesel prices back down? Biodiesel investors would have to choose whether to respond by expanding plantation areas or not. In the short run, palm oil prices would rise as the current stock of palm oil was diverted to biodiesel production. Food consumers would face higher prices. In the long run, if diesel prices fell, then palm oil prices would fall with them. Palm oil prices could even overshoot – falling further than diesel prices – if investors with false expectations had expanded supply in response to the temporary fuel price shock.

Table 5-7 summarizes three scenarios for future palm oil demand, based on hypothetical changes in policy and petroleum prices. A sustained rise in diesel prices would lead to higher palm oil prices and new investment in palm oil plantings, shifting out supply and palm oil production in the long run. Palm oil consumption for food would be curtailed. In contrast, a temporary diesel price spike would induce short term increases in palm oil's price but would likely not have large effects on palm oil plantings and supply.

What about mandates? Biodiesel mandates and subsidies in Europe, currently the world's biggest biodiesel consuming region, could conceivably be removed due to new concerns about biodiesel's environmental costs (particularly with regards to land conversion for agriculture). In this case, vegetable oil prices would fall and vegetable oil availability for food consumption would increase. The first order impacts would be on rapeseed oil, the most common feedstock for biodiesel in Europe, but prices would also fall for palm oil to the extent that these two oils are substitutes.

Table 5-7 Future biodiesel scenarios and demand for palm oil.

	Sustained higher diesel price	Diesel price spike	Mandates lifted
Consequences for palm oil markets	Higher palm oil prices, higher palm oil production, and higher short-run revenues for palm oil producers that will eventually shift out the palm oil supply curve. Palm oil consumption for food declines as prices rise.	Temporarily higher palm oil prices as existing biodiesel capacity comes on-line. Limited new biodiesel investment or new palm oil plantings if the diesel price spike is perceived as temporary (new palm oil trees take several years to mature). Palm oil is temporarily diverted from the food supply.	Lower prices for palm oil and higher palm oil consumption for food. Possibility of a small downward adjustment in rates of re-planting.

Conclusion

The potential market for palm oil as a biodiesel source is huge, especially at the right set of relative prices. Even without high diesel prices, mandates could make a big difference to palm oil demand. Global biodiesel production in 2010 was 19 billion liters, which corresponds to an equal volume of vegetable oil feedstock. By comparison, global palm oil consumption was 54 billion liters. If palm oil, as the cheapest vegetable oil, by itself fulfilled world biodiesel mandates as they are implemented today, then – assuming perfectly elastic supply – palm oil consumption would increase by 35 percent.

In response to a rapid, dramatic new source of palm oil demand, palm oil prices would rise and food consumption would adjust. Higher palm oil demand for biodiesel could result from a switch between feedstocks under existing subsidy regimes; new subsidy regimes; or from rising diesel prices.

At the end of the day, the most important factors determining biodiesel's impact on palm oil markets are: (1) what will happen to the price of diesel relative to palm oil; (2) what will happen to palm oil supply (a function of land use, non-land input supply, and technological change). If palm oil supply is more elastic than palm oil demand, then in response to a shock, supply will increase more than palm oil demand falls. From an environmental perspective, the extensive supply margin for palm oil is particularly critical, as it determines the rate of new land conversion for oil palm. Yield increases will not have the same detrimental impacts on carbon stocks and biodiversity as expansion would.

Highly inelastic palm oil supply would imply that diesel prices have to rise higher (relative to an inelastic supply function) to make biodiesel profitable. Mandates could drive higher palm oil production (and higher palm oil prices); but, as was the case in Malaysia, government mandates likely would not withstand significant movements in palm oil's price.

From a development perspective, inelastic palm oil supply and higher prices would encourage new producing regions with higher production costs (e.g. in Africa) to enter the market. Higher palm oil prices could also negatively affect food consumption and nutrition, particularly in urban areas. A world where diesel prices rise, pulling up palm oil prices in their wake, would induce severe changes in the world vegetable oils market. Some of these implications are discussed in the following chapter.

Chapter 6 Implications of the research for land use change

This thesis demonstrates that, despite lower growth rates for palm oil consumption, the level of palm oil demand for food is likely to double over the next twenty-five years in Indonesia and in the world as a whole – to say nothing of the even greater production increases that may be needed to meet future demand for palm-based biodiesel. Such large demand increases will necessarily have implications for palm oil supply and land use. On the supply side, the projections in this thesis rely on a partial equilibrium model that assumes prices will remain constant over the next twenty-five years; that is, that a doubling of demand can be met with no additional price incentives to producers beyond those that are currently in place. How reasonable is this assumption? How much land is in fact available for expanding palm oil production and palm oil plantations, and how much scope is there for yield increases in palm oil production? Further, even if the private profitability of producing palm oil at current prices is sufficiently high to meet demand, how do the private costs of expanding palm oil plantations compare with the social costs imposed on communities, countries, and the world?

Currently, the vast majority – 84% -- of palm oil is produced in just two countries in Southeast Asia: Indonesia and Malaysia. That palm oil production is so concentrated geographically is surprising, given the fact that other countries' agro-climates are well suited for growing oil palm: oil palm grows best within a tropical band plus or minus ten degrees from the equator. The dominance of large-scale palm oil plantations in Malaysia, and then in neighboring Indonesia - despite the agro-climatic suitability of agricultural and forest areas elsewhere - is partly an accident of history. During the Industrial Revolution in Europe, Malaysia's British colonial government discovered that palm oil plantations could help to meet a large and growing demand for soap in Britain. Over time, as land and labor have become more scarce and more expensive in

Malaysia, private palm oil investment has spilled over into Indonesia to fulfill growing demand. The area planted to palm oil is higher now in Indonesia than in Malaysia, although Indonesia's yields are currently lower.

Large-scale plantations have spread in Malaysia and Indonesia partly at the expense of forests. Gibbs et al. (2010) measure that roughly half of new tree plantations in Southeast Asia came from cropland in the 1980s and that nearly 70% of new plantations came from cropland in the 1990s. The remainder of the land for new plantations came from forests (Gibbs et al., 2010). Koh and Wilcove (2010) estimate that a larger fraction, half, of new plantations came from forest in the period 1990 – 2005. Recent analysis shows that the fraction of new plantations located on carbon-rich peat lands in West Kalimantan is increasing (Carlson et al., 2012). Expanding oil palm plantations presents trade-offs both with other food crops and with ecologically-valuable forests.

Which land areas will be converted next? A doubling of palm oil production over the next twenty-five years, as predicted in this thesis, will have to come from somewhere. At current global average yields, doubling production would require an additional 15 million hectares of land.

Higher yields on existing palm oil plantations will meet part of the new demand in the future, both through improved management of existing trees and through replacement of trees, as they mature, with higher-yielding varieties. Oil palms need replacing approximately every 25 years as yields decline, and then there is a 3-5 year lag before the new trees will produce fruit. This means that yield improvements from improved seed varieties will deploy more slowly than in the case of an annual crop. Nevertheless, the potential for increasing average yields on palm oil plantations is high, since agronomic research on oil palm production is still in its infancy. New tissue culture cloning techniques in Indonesia are on the verge of producing seeds that have twenty percent higher yields than existing varieties (Liwang, personal communication). In 2009, a consortium of researchers succeeded in sequencing three oil palm genomes, which could lead to even further genetic improvements (Schill, 2009). Even without new improvements in planting material, better management techniques could dramatically improve yields on both mineral soils and marginal, sandy soils (Fairhurst, personal communication). Globally, the exploitable yield gap for oil palm is high. Nigeria, as an illustration, has close to one quarter of the world's oil palm planted area, yet yields are only one half of those in Ghana and only one eighth of those in Malaysia (Deininger et al., 2011).

Global average palm oil yields have increased at the rate of about 0.06 tonnes per hectare per year over the past twenty-five years. Extrapolating this trend linearly into the future implies global average palm oil yields of 4.4 tonnes per hectare in the year 2035 – enough to accommodate a 30 percent increase in palm oil production with no land expansion, but not a 100 percent increase. At 4.4 average global tonnes per hectare, doubling palm oil production would require an additional 8.1 million hectares of land for oil palm plantations. Yields will increase faster if it is relatively more expensive to acquire new land, so the availability of undeveloped, suitable areas for new oil palm plantations is critical.

Within Malaysia, the amount of new land that could be developed for oil palm plantations is likely to be small, unless there are unexpected and radical changes in the use of crown land. Malaysia has sustained dramatic increases in palm oil area since 1985, increasing plantations from 1.2 million ha to 4 million ha in 25 years -- an annual growth rate of almost 5 percent per year (FAOSTAT). At the same time, forest cover in Malaysia's palm oil producing regions has declined. Malaysia's forest cover is currently at 58% - barely above Malaysia's national goal of retaining 50% forest cover in perpetuity (USDA, 2011a). According to industry, this forest-cover goal implies a cap on plantation areas of 5.6 million ha, or 750,000 ha in addition to currently planted areas. At current rates of expansion, if the government adhered to its 50 percent forest cover target, Malaysia would run out of land for new plantations in only six years (USDA, 2011a). Adding to Malaysia's production constraints is the fact that much of Malaysia's undeveloped land is in less-productive (and more carbon-rich) peat areas or in degraded forest with contested land ownership.

Indonesia is quickly arriving in a similar situation. Indonesia's potential land area is larger, though much of the land that could be developed is fraught with overlapping ownership claims, labor shortages, and / or high environmental costs. In Indonesia, the area planted to oil palm has grown over 11 percent per year since 1985 (FAOSTAT). According to Indonesian national statistics, oil palm plantations currently occupy 4.5 million ha[48] (BPS, 2009; Fortson, 2011) out of a total agricultural area of 54 million ha and a total forested area equal to 95 million ha (Food and Agriculture Organization, 2011). Indonesia is currently losing over one million ha of its forests – the largest forest expanse in Asia and some of the most biologically rich forest in the world -- each year (Hansen et al., 2009). Despite the physical possibility of converting more lands to oil palm plantations, Indonesia is under intense pressure not to expand oil palm areas. In 2009, Indonesia's Minister of Agriculture indicated that 18 million ha of new land were available for new plantations ("Indonesia Allocates 18 Million Hectares of Land for Palm Oil," 2009). In 2011, Indonesia's government conceded to international pressures and imposed a moratorium on clearing primary forests and peat lands for palm oil plantations. This moratorium excludes existing concessions and 'degraded' lands, so the law by no means spells the end of palm oil expansion in Indonesia. By one estimate, Indonesia could double its palm oil production by expanding into 5.4 million ha of degraded land and converting existing agricultural land equal to 66% of Indonesia's rice production potential – with limited impacts on biodiversity (Koh & Ghazoul, 2010). However, given the importance of domestic rice production to Indonesian food security, doubling palm oil production without impinging on any new forests seems an unlikely scenario. More likely is that some of the extensive forested areas in West Papua province will be converted, with exceptions for "high conservation value" forest, and with labor imported from elsewhere in

[48] Other sources put this number at 5 million ha (FAOSTAT).

Indonesia as necessary. While Golden Agri has lost its concession to develop one million hectares for oil palm in Papua, smaller concessions still exist ("Cover Story: Plantation Mirage," 2010). West Papua represents a new frontier – after Sumatra and Kalimantan – for palm oil expansion in Indonesia.

Beyond Southeast Asia, oil palm plantations, profitable as they are in the current demand environment, are inevitably finding new tropical niches. Oil palm plantations have already been established across Africa and Latin America. According to FAO estimates, Africa had 4.5 million ha planted to oil palm in 2010, while Latin America had 700,000 ha (FAOSTAT 2012).

In Africa, the extent of oil palm is difficult to measure because much of the oil palm exists as smaller groves or natural palm stands. Nigeria, Ghana, and Cote d'Ivoire all have large areas of existing, relatively low productivity plantations. In Nigeria, 80 percent of the palm oil is grown by smallholders on dispersed plots of land and processed by hand, typically by women (Carrere, 2010). Throughout the first half of the twentieth century, West Africa was the center of the global palm oil industry -- it was farmers in this region who originally domesticated the oil palm. In 1980, sub-Saharan Africa was still a net exporter of palm oil, but today, sub-Saharan Africa is a net importer (World Bank & IFC, 2011). As a region, Africa has extensive land that is planted to oil palm or that is suitable for planting oil palm, but yields are low. Raising palm oil yields in existing oil palm producing regions of Africa would significantly increase global palm oil supply.

Oil palm investments by Malaysian and Indonesian companies are in the process of changing the structure of palm oil production in Africa and vastly increasing Africa's production potential. In Liberia, for example, the Malaysian company Sime Darby and the Indonesian producer Golden Agri Resources (a subsidiary of Sinar Mas) have committed 4.7 billion dollars to develop 450,000 of land for oil palm. In addition to the existing areas that are planted to oil palm, vast amounts of new land in Africa would be highly suitable, from an agro-climate perspective, for growing oil palm. The Congo (DRC), for example, has 778,000 ha of forest that would be suitable for oil palm, the second largest suitable forest area in the world, after Brazil (Stickler, Coe, Nepstad, Fiske, & Lefebvre, 2007). Given land and labor constraints elsewhere, there is no doubt that Africa will feature prominently in the global palm oil economy over the next twenty-five years, both as a consumer and as a producer. The expansion of the palm oil industry in Africa will likely bring rural development benefits, disrupt existing land ownership structures, and displace forests (Butler & Hance, 2011). Expanding the local vegetable oil industry could also have positive implications for food security in urban areas.

Like the Congo and other African countries, Brazil has much land that could be converted to oil palm plantations. Brazil is the country with the largest forested area suitable for oil palm: nearly half of Amazonia could, in theory, be used to grow the crop (Butler & Laurance, 2010). In May 2010, Brazil's president announced his plan to develop close to 5 million ha for oil palm plantations in Brazil without converting any native forests (World Bank & IFC, 2011). Brazil has significant amounts of deforested land that could be developed as plantations, and advanced satellite monitoring in Brazil will help with enforcement. In practice, stricter land regulations in Brazil mean that production costs could be as much as twice as high as they are in Southeast Asia (Butler, 2011). In addition to stricter deforestation laws, Brazilian palm oil plantations face constraints on obtaining quality planting material (seeds) and labor. If these constraints can be overcome, Brazil and other countries in Latin America will join African countries as new centers of palm oil production growth.

Higher production costs, such as those faced by new producers in Brazil, may be the most reliable way to stem higher palm oil consumption, higher production, and the enormous land use changes - including deforestation – associated with the palm oil revolution. Social costs, including the cost of carbon emissions and biodiversity loss from deforestation, need to be included in the private cost of developing land for new plantations. As long as palm oil prices stay low, vegetable oil consumers will choose palm oil over other oils, and demand will continue to grow. If palm oil becomes more expensive relative to substitute oils, then demand could fall. The best way to limit the development of new large-scale palm oil plantations would be to increase palm oil's production costs (for example, by limiting access to new land), thereby making palm oil less competitive with soybean oil, rapeseed oil, and other oils. Research on improved environmental production practices and supply-side constraints to palm oil expansion is particularly important in light of the high substitutability between vegetable oils and the impact of substitution on palm oil demand.

In contrast to stricter land-use regulation, raising yields on palm oil plantations will hardly slow the rates of palm oil-associated deforestation, since – as long as palm oil's price does not increase – palm oil's market share will grow and demand will rise accordingly (assuming that the prices of diesel and substitute vegetable oils remain unchanged). Similarly, opening up large amounts of new land in Latin America or Africa will not spare Indonesia's remaining forests in Kalimantan. The important implication of this thesis is that potential demand growth for palm oil at current prices is very large – almost as large as the entire vegetable oils market.

In a very broad sense, altering the world's vegetable oil consumption patterns to include more palm oil would reduce the global area devoted to growing oil crops. Yields for oil palm are as much as ten times as high as the yields for other vegetable oils; so, under this scenario, less of the world's land surface might be devoted to growing vegetable oils - leaving more land available for biodiversity habitat and other uses (Green, Cornell, Scharlemann, & Balmford, 2005). However, the geography of agricultural land use would change. If current substitution trends towards palm oil continue, the world may eventually see less rapeseed or sunflower production in temperate climates and much more palm oil production in tropical Southeast Asia, Latin America, and Africa. The trend towards higher palm oil consumption represents a new era of tropical agriculture.

One of the key questions for the future is how to steer oil palm production towards non-forest areas, thus adding net carbon sequestration and protecting biodiversity. In addition, institutional arrangements for oil palm production need to protect smallholder land claims, share oil palm profits fairly, and mitigate the risks associated with selling into a volatile global commodity market. Oil palm agriculture has the potential to be a pro-poor development strategy that sequesters carbon while yielding an affordable source of calories. Whether demand growth for oil palm will be coupled with improved livelihoods, nutrition, and a healthy environment has yet to be determined.

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