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PALM OIL PLANTATION PRODUCTIVITY DURING THE ESTABLISHMENT OF THE MALAYSIAN REFINERY SECTOR 1970–1990

ABSTRACT

The Malaysian palm oil sector is an example of how a developing country can manage to establish itself as a world leader in the production and processing of an agricultural crop. This paper examines the formative period (1970–1990) of the Malaysian palm oil industry by focusing on the productivity at the plantation level, the first level of production, to understand how this process influenced the establishment of the higher value-added refineries. The paper finds that the official productivity figures, the oil yield (metric tonnes of crude palm oil per hectare), is inconsistent and estimates more consistent productivity figures. In addition, the paper briefly considers labour productivity as the Malaysian palm oil sector is more labour-intensive than its competitors. The main finding is that the improvements in plantation productivity were crucial for the development of the palm oil processing refinery sector, which might hold important implications for other developing countries wishing to promote agricultural processing industries.

Keywords: palm oil, industrial policy, East Asia, productivity

JEL Codes: N25, O13, O25, Q17

Introduction

The Malaysian palm oil sector is an example of a sector that contributed to economic growth through the processing of primary commodities, in this case food processing. Cramer (1999) is one of many to emphasize that such processing could contribute to industrialisation in developing countries. The potential benefits of exporting higher value-added processed primary commodities include (i) increased employment creation; (ii) increased linkages; (iii) increased productivity growth; and (iv) greater price stability. However, there are a number of constraints that developing countries need to overcome to be able to successfully develop a primary commodity processing industry. The external constraints include the barriers to entry caused by existing multinational firms that already dominate the international market in addition to trade barriers such as quality requirements and tariffs. Internal, or domestic, constraints include the need for a skilled labour force and the need for capital, as primary processing industries in general are capital-intensive. The Malaysian palm oil sector was able to overcome these constraints, and develop an internationally competitive food processing industry in the form of the Malaysian palm oil refineries.

Probably the most important mechanism in overcoming these constraints was the strong government support give to palm oil refineries through both industrial policies and institutions that were vital for functional areas such as research (Gopal, 2001). This support is consistent with the industrial policy literature in overcoming entry barriers to the international markets (Rodrik, 2008; Chang, 2009). Despite being relevant, this literature does not primarily focus on food-processing industries. These industries have an additional dimension in comparison to for instance textiles or high-tech industries, as they are dependent on food production. In Malaysia, the success of the industrial policy mentioned above is linked to the performance of the food-producing units, namely the palm oil plantations.

Palm oil plantations are the first level of the value-chain, and provide the palm oil refineries with the necessary input material. These plantations showed little increase in productivity according to the official figures (going back to 1975), indicating that the increase in productivity was of little importance to the development of the palm oil refineries. [1] However, the current paper finds inconsistencies in the official productivity figure, the oil yield, which measures the amount of crude palm oil (metric tonnes) per mature area (hectare). The current paper therefore re-estimates the oil yield, and finds that productivity increased by more than the official figures suggests. As the oil yield is a partial productivity measure. In addition, labour

[1] Productivity itself is defined as the growth of output not accounted for by the growth of inputs (Ahearn *et al.*, 1998).

productivity is briefly addressed to give a clearer picture of the overall productivity performance of plantations.

The Malaysian palm oil sector has attracted much research. Corley and Tinker (2015) is the latest update of Hartely's Oil Palm and explores the origins of the industry and the specifics of oil palm cultivation. Khera (1976) and Moll (1987) provide detailed accounts of the establishment of oil palm industry including cost analysis. Gopal (2001) focuses on the establishment of the palm oil refineries, and how this industry overcame the common barriers to entry that developing countries face when establishing food-processing industries. However, Gopal to a lesser extent focus upon the development of productivity at the lower stages of production. Other research focuses on productivity growth (Jalani *et al.* 2002; Soh and Goh 2002, and Wahid *et al.* 2005). Much of this research attempts to explain why productivity growth according to the official figures has been slow, which often is attributed to the lack of implementation of new technology. However, no study, to my knowledge, has explicitly looked at the relationship between plantation productivity and the establishment of palm oil refineries. This paper attempts to fill that gap.

As such, the research question is as follows: 'Was plantation productivity important for the establishment of the palm oil refinery sector?' This paper adds to the literature in three ways. First, the paper aims to give a clearer picture of how productivity evolved at the plantation level in the formative years of the palm oil sector from 1970 to 1990. Second, the paper aims to increase our understanding of the importance of plantation productivity for the establishment of the refinery sector. Finally, the paper aims to increase our knowledge about how plantations can contribute to the economic growth process by increasing the value-added of the production structure.

World market for palm oil

Palm oil has grown from a relative minor to one of the major agricultural crops in the world. There is a large degree of substitution between various oils (animal and vegetable oils and fats) meaning that these are competing with each other.[2] Exports of oils has been increasing since 1961 and palm oil is currently the most traded and produced oil in the world (Corley and Tinker, 2015). The increase in demand for oils has been high following 1961, real prices have however decreased up until 2000 (Fry 1998). From 1975 to 1993 the global demand for vegetable oils, measured as the total export value in fixed prices rather than trade volume, was only increasing

[2] See for instance Moll (1987) and Amiruddin *et al.* (2005).

by a compound annual growth rate of 0.5 % (FAO 2014). In the same period, the market share of palm oil was increasing (from 22.9 % in 1975 to 33.5 % in 1993). Export value for oil increased much more rapidly from 1993 to 2013 (annual compound growth rate of 8 %), whilst the market share of palm oil continued its trend, comprising of 44.6 % of all oils in 2013.[3] From 1970 palm oil's share of total exports increased, and is therefore a natural starting point for an analysis of its success.

One of the key factors contributing to the rise of palm oil in this period was the role of the Malaysian palm oil sector. In 1961, Malaysia ranked fourth with an export share of 13 % (FAO 2014). However, Malaysia's spectacular growth in palm oil production and exports saw it becoming the major palm oil exporter within a decade. Malaysia's market share reached a peak at 72 % of world exports of palm oil in 1983, and the market share was above 60 % each year from 1979 to 1996 (above 50 % from 1975 to 2004). Since then, Indonesia has increasingly taken over as the major player. Indonesia and Malaysia have near perfect climatic conditions for producing palm oil with a tropical climate and stable rainfall all year round, giving them a strong natural advantage in the production of palm oil (Moll 1987). Most of the industry expansion prior to the 1990s was in Malaysia, which in many ways laid the foundation for the modern palm oil industry.

The period 1970-1990 also marked a shift in the main export markets of the Malaysian palm oil sector. In 1970, the main importer of Malaysian palm oil was the United Kingdom: most of the palm oil going to Singapore was re-exported to the United Kingdom.[4] Given the export figures from Singapore, roughly 46 % of all exports (directly and via Singapore) were to the United Kingdom. By 1990, the situation had changed drastically as China became the major importer (which it is still was in 2010), with exports to the United Kingdom being negligible. In fact, while the main export markets in 1970 were developed countries, the main export markets in 1990 were developing countries, making the palm oil sector an example of growth through South-South trade. However, these figures hide one of the main causes of the shift in export markets, namely that the main product being exported has changed over time. In 1970, exports were almost exclusively crude palm oil, processed in refineries in Europe and in the United Kingdom in particular. In 1990, exports were almost exclusively processed palm oil, which already had been processed in refineries in Malaysia prior to being exported.

[3] The export shares of its closest competitors were 13.0 % (soybean oil), 12.3 % (sunflower oil) and 8.8 % (olive oil, includes both virgin and residues). All figures from FAO (2014).
[4] All figures from UN (2016).

To explain the difference, it is useful to divide the palm oil sector's production process into three levels. *Plantations* produce the palm oil fruit from the palm trees; these fruits are called fresh fruit bunches (FFB). Following detachment from the palm tree, processing of FFBs must take place within 24 hours to have sufficient quality. *Mills*, the second level, process FFB to produce crude palm oil (CPO), and as a by-product, palm kernel (PK). As the processing of FFBs has to be quick, mills are located close to, or even on, the plantations. *Refineries*, the final level, process CPO to produce various products called processed palm oil (PPO). CPO, PK and PPO products can also be used as inputs in other industries such as the oleochemical industry. During the 1970-90 period, the higher value-added refineries and the linkages to other industries were established. Figure 1 presents a schematic summary of the industry with some of its forward linkages. To limit the scope of the current paper, I do not consider palm kernel or palm kernel oil, but focus on crude palm oil. In addition, as plantations and mills are highly integrated, this paper looks at the productivity of both plantations and mills and how it affects the palm oil refineries. For further introductory overviews of the palm oil sector, see Moll (1987), Rasiah (2006) and Corley and Tinker (2015).

[INSERT FIGURE 1 HERE]

A key question is whether the expansion of the palm oil sector would have been possible without the establishment of the refineries. This is a counterfactual question which by its design is difficult to give a definitive answer. However, there are a number of arguments that support that refineries did play a crucial role. First, the refineries increased investments in palm oil plantations as the government commitment to the sector played a crucial role (Gopal 2001). Second, the alternative export strategy, to continue to export crude palm oil, would likely have stagnated eventually. Shipping costs were already an issue in the beginning of the 1970s and would likely to have increased the number of ships and the quantity of crude palm oil transported would have increased costs even further (Khera 1976). In addition, international trade in agricultural products is prone to protectionist policies in developed countries, and vegetable oils are no exception. Third, the dependence on the United Kingdom would have been too risky. British refineries did not rely solely on palm oil, but could also use other vegetable oils as input in its production process. If prices of other oils, which might be protected within the EU would have declined as a result of protectionist policies, it would have been easy for British refineries to substitute to other oils. Finally, the investments in refineries in Malaysia led to a large increase in agricultural research and development, and led to an increased focus on developing innovative solutions to process large quantities of palm oil. This research and innovation could have positive externalities for other sectors in the economy. In the next section, the establishment of the refineries is explored in more detail from a domestic point of view.

Establishment of the Malaysian palm oil sector

The modern expansion of the sector started in the 1960s, though commercial production of palm oil first started in 1917 (see table 1). In colonial times, the palm oil sector was slow to develop, with production and exports increasing only modestly (Pletcher 1990 p.329). In the 1960s, the government strongly promoted palm oil as part of a strategy of reducing the Malaysian dependence on rubber and tin. Substantial replanting grants were given for planters shifting from rubber to palm oil (Pletcher 1990 p. 337). Favourable prices and operating costs that were potentially lower than rubber made palm oil a natural long-term replacement for rubber (Khera 1976 pp.47-66; 82-124). Crude palm oil production increased rapidly, increasing from a 5.4 % compound annual growth rate 1950-60, to 16.7 % 1960-70.[5] According to Moll (1987 p.141), there were four specific reasons for the rapid expansion of the palm oil sector; (i) Climatic and soil advantages which made palm oil suitable; (ii) Virgin land that the government could allocate; (iii) The plantation system already in place for rubber, could easily be changed to growing palm oil; and (iv) The introduction of new technology, initially from abroad but later Malaysians developed many new ones themselves.

[INSERT TABLE 1 HERE]

Following the rapid increase in crude palm oil production and exports in the 1960s and early 1970s, the structure of the industry changed. The government believed that a continued increase in exports hinged on increasing value-added. To increase the value-added, the government promoted the establishment of the refinery sector through investment and tax incentives, and most importantly, an export tax on crude palm oil while processed palm oil had duty exemptions, starting in 1968 and revised several times thereafter (Gopal, 2001 pp.274-298). The export tax increased the cost of crude palm oil for European refineries and led to increased investments in palm oil refineries in Malaysia. The World Bank opposed the export tax, as Malaysia did not have a comparative advantage in capital-intensive production. British

[5] Based on data from Gopal (2001) and Department of Statistics (various years).

plantation owners in Malaysia also opposed the tax, as they preferred to have palm oil processed in Europe. According to Bek-Nielsen, the founder of United Plantations, the British plantation owners were afraid of upsetting Unilever, their biggest customer, who preferred to process the vegetable oils in Europe (Fold, 1998 p.401). United Plantations themselves responded to these incentives by being among the first palm oil plantation owners to invest in their own refinery (Martin 2005 pp.199-254).

The World Bank scepticism is related to the general question of whether developing countries should process their agricultural goods. The literature on resource-based industrialisation and exports focuses largely on the barriers to market entry.[6] The traditional comparative advantage argument, with its neoclassical foundations, has been criticized for being static as comparative advantages might be dynamic. In addition, capital-intensive industries, such as the refinery sector, have a considerable economics-of-scale. Industrial policies to promote the refinery sector could work in theory, as the initial entry barriers are overcome and the industry gradually becomes more competitive. [7] In practice, however, if the industry does not exhibit learning over time it might result in a "white elephant" problem with the industry becoming a drain on fiscal resources.[8]

Despite the initial scepticism, the palm oil refinery sector in Malaysia enjoyed high export growth for its products and increased competitiveness over time. Refineries increased their processing capacity from below 0.1 million tonnes in 1971 to close to 10.5 million tonnes in 1990 (see table 2). Table 2 also reveals that the average size of refineries gradually increased over time. since it was a capital-intensive industry, the refineries had considerable economies-of-scale to exploit. In addition, most of the oil processed at the refineries came from domestic producers of CPO, as the expansion of the processed quantity was closely correlated with increases in local production from 1980 and onward. There was a dramatic change during the 1970s, when CPO processed compared to CPO production was only 4 %, but this figure increased to 95 % by 1980 and has since been at a minimum around 90 %. Figure 1 presents more evidence of the increased importance of refineries as processed palm oil replaced crude palm oil as the main palm oil export product in the 1970s and has kept this position ever since. Early studies by Todd (1978) and Lim (1979) had concluded that the Malaysian palm oil refinery industry was not competitive at the end of the 1970s. Gopal (2001) re-analysed the competitiveness of the palm oil refineries by comparing the profit margins for Malaysian

[6] See Roemer (1979), Cramer (1999) and Gopal (2001).
[7] For an overview of the literature see Rodrik (2008) and Chang (2009).
[8] A "white elephant" is an investment project with a negative social surplus, see Robinson and Torvik (2005) for an elaboration.

refineries at domestic and border prices from 1980 to 1994. Gopal's analysis strongly indicates that the Malaysian refineries became more competitive than the European ones towards the end of the 1980s.

[INSERT TABLE 2 HERE]
[INSERT FIGURE 2 HERE]

Several factors contributed to the increased competitiveness of the palm oil refinery sector. The most important factor is probably that cost efficiency at Malaysian refineries increased through learning-by-doing. In addition, the refineries went through two restructuring processes in which ineffective refineries went bankrupt. Another important point is that Malaysian refineries had a higher degree of specialisation than the European ones. European refineries used various vegetable oils to produce processed oil products; Malaysian refineries almost exclusively used palm oil. Such specialisation did create technological challenges that led to the development of new technologies by Malaysian refineries to treat large volumes of palm oil (Gopal 2001, pp.141-142). Malaysia increasingly became the main innovator within the industry as it met the challenge of creating palm oil-specific technology. The refineries probably benefited from this development, as the specialisation led to efficiency gains over their European rivals.

By the second half of the 1980s, the palm oil industry had matured and was increasing its backward and forward linkages to other industries, the most important of which has probably been the oleochemical sector. Following 1990, the growth of this industry has largely continued the trends that were forthcoming in the 1980s with processed palm oil being the industry's major product. To understand the establishment of the palm oil sector, it is therefore important to focus at the 1970-90 period.

The state played a decisive role in the development of the palm oil sector, which partly is related to the New Economic Policy (NEP) implemented in 1970. The NEP was a response to racial riots in 1969, and its main purpose was to increase income and reduce income inequality especially for the largest and poorest ethnic group, the indigenous Malaysian population, the *Bumipureta*. The role of the state was especially important in four areas. The first was the above-mentioned promotion of the higher value-added palm oil refineries to increase income and decrease foreign dependence through export and tax incentives. The second was through government schemes, as the state was directly involved in production. The most important of these schemes was the Federal Land Development Authority (FELDA), which changed its focus during the period from being a purely poverty reducing institution to becoming a commercially active state company.[9] The third area was in establishing supporting institutions. The Palm Oil Registration and Licensing Authority (PORLA) was responsible for giving licences, controlling prices and ensuring the quality of palm oil. The Palm Oil Research Institute of Malaysia (PORIM) was responsible for conducting public research in palm oil. Following a rationalisation process in 1998, PORLA and PORIM merged to form the Malaysian Palm Oil Board (MPOB). The government is also the main owner of the current Malaysian Palm Oil Council (MPOC); a private company that promotes palm oil by launching marketing campaigns and trade missions.[10] The final area, and arguably the most controversial, was the state's purchase of most of the foreign-owned palm oil plantations to increase the equity share of indigenous ownership (Pletcher 1991 pp.630-631).[11] Among the most well-known examples are the takeovers of Sime Darby in 1976 and Guthrie in 1981 (Martin 2005 p.255). In 1968, non-Malaysians controlled 46.8 % of all plantations in Peninsular Malaysia, but this constituted 78.2 % of all plantation land as foreign plantations were larger.[12] By 1983, non-Malaysians controlled 9.9 % of all plantations and only 8.6 % of all planted plantation land.[13] Although not achieved through expropriation, the takeovers were still aggressive. Public funds were used to purchase shares from foreign companies, which subsequently were sold to Bumiputera.[14]

Direct government involvement in agricultural markets has been much criticized.[15] However, in the case of the Malaysian palm oil sector, heavy government involvement has been compatible with high growth. Pletcher (1991 p.624) mentions several factors that have been important for successful state intervention. One is that the price mechanism was never officially controlled, even though it was influenced. The wedge between world and domestic crude palm oil prices created by the export tax were especially important, which is commented upon later. Another important point according to Pletcher (1991) was that the policies that helped shape the palm oil sector were internally consistent and consistent across time.

The importance of industrial policies for the palm oil sector is therefore well established. However, no paper to my knowledge has previously considered how plantation productivity,

[9] On the evolution of FELDA regimes, see Pletcher (1991 pp.628-630).
[10] See also Simeh and Ahmad (2001 pp.2-4) for an overview of the government institutions in the palm oil sector.
[11] The change in ownership was not forseen by all prior to the take-overs. Khera (1976) p.140 wrote "In no other newly independent country in the tropics are foreign owned estate enterprises so important in the national economy, and they continue to be accepted as having a major role to play in future economic development."
[12] All figures from the Department of Statistics (various years).
[13] This figure actually overstates the foreign influence in the palm oil sector as the government schemes and smallholders grew faster than plantations in the period from 1968 to 1983, meaning that the total share of foreign-owned palm oil land was around 4.8 % in 1983.
[14] For more details on plantation takeovers, see Pletcher (1991) pp.630-631; Martin (2005) pp.255-283.
[15] See for instance Timmer (1986).

the first level of processing, is related to the establishment of the refinery sector.[16] It is an important consideration as it might determine whether an industrial policy might be successful. According to the official figure, the land productivity measure, called the oil yield, has been virtually stagnant since 1975. The oil yield measures crude palm oil production per mature area (area which is harvested) and is a joint productivity indicator of both plantations and mills. As crude palm oil is the major input for the refinery sector, the official figures tells the story that an increase in productivity since 1975 was not necessary for the expansion for the palm oil refineries. However, the current paper claims that the official figures do not represent the true productivity increases as a number of inconsistencies were found in these figures. This paper therefore re-estimates the oil yield and uses this newly constructed oil yield to consider the role of plantation productivity. The analysis will go beyond merely measuring land productivity and also measure labour productivity, as the palm oil sector is more labour-intensive than its main competitors.

The fundamental question is still whether an increase in productivity was necessary for the expansion of the palm oil sector. As profit margins were high, the competitive pressure to increase oil yield may have been limited. However, there are several arguments for why the aggregate productivity figures might understate the development of productivity over time. Productivity on existing plantations may have increased, but since new plantations were being established in marginal areas with lower yield potential, the aggregate productivity still remained more or less constant. Normally, the land with the highest quality is taken into production first, meaning that a future expansion into new areas meant that land quality in terms of yield potential decreased. Producing the same quantity despite a decrease in the quality of inputs would therefore be a *de facto* productivity increase. Another argument is that increased market entry might understate productivity. New plantations would initially be less productive, as productivity first increases through learning-by-doing. If a sufficient number of new plantations were established, the average productivity levels might decrease.

As Cramer (1999) mentions, we know little about how food processing industries are established in developing countries. In the case of the Malaysian palm oil sector, it is clear that industrial policies played a vital part. The question addressed here is whether an increased productivity at the plantation level was an important precondition for developing a downstream food processing industry. By extension, the issue addressed is whether plantation productivity was important for the success of the industrial policy in the Malaysian palm oil sector.

[16] Productivity is defined as the amount of output that can be produced given the amount of input.

Productivity Measures in the Palm Oil Sector

The main indicator of productivity has been the previously mentioned oil yield, which is a mixed land and processing productivity measure. The most commonly used methodology in the productivity literature is a total factor productivity analysis (Ahearn *et al.* 1998). However, data limitations, especially the lack of capital data for the 1970s, hinder such an analysis.

Instead, the analysis focuses on the oil yield, as it is the most used productivity measure. Its advantages is its accessibility and comparability with other vegetable oils. In addition, the quality of the data is better than for other productivity measures. However, as mentioned above, the official figures have some major inconsistencies. These are corrected using an alternative method for estimating the oil yield, which produces an increasing rather than stagnating productivity. As the oil yield measures partial productivity, it does have the major disadvantage of not considering other inputs. Palm oil is different in terms of its production process compared to other vegetable oils. Davidson (1993) summarizes this difference elegantly: "the oil palm is six to seven times more labour demanding than major competitors, but it can produce anything up to ten times more oil per unit area". Given its importance, the current paper also estimates the evolution of labour productivity uses data from the Department of Statistics. Appendix 3 also combine the land and labour productivity figures to construct a multifactor productivity estimate of productivity.

Oil Yield

The oil yield data taken directly from the MPOB differs from the FAO data. According to MPOB data, the oil yield increased from 3.7 metric tonnes per hectare (mt/ha) in 1975 to 3.9 mt/ha in 2009, an annual compound growth rate of 0.2 %. However, according to FAO data, yield increased from 3.5 mt/ha in 1975 to 4.3 mt/ha in 2009. The FAO data give an annual compound growth rate of 0.6 % in the same period. The FAO data thus shows a growth rate that is three times as high as the MPOB data. Fry (2009) also noted the difference, which he attributed to the unreliability of the FAO data. However, both production and end of year mature areas are identical for both the official MPOB data and the FAO data for the period 1975-2011. The difference in the yield figures has an easier explanation, since the formulae for calculating oil yields differ, as illustrated in equations (1) and (2):

$$\text{MPOB CPO Yield} = \frac{\text{Yearly CPO Production}}{\text{Average Mature Area in Production During the Year}} \qquad (1)$$

$$\text{FAO CPO Yield} = \frac{\text{Yearly CPO Production}}{\text{Mature Area at the End of the Year}} \qquad (2)$$

Normally, this difference would be unproblematic as the trends would be approximately the same. However, the trends are not the same, meaning that one of these is probably inconsistent. Palm kernel (PK) is, as mentioned, a by-product of the palm oil sector. Both CPO and PK are produced from fresh fruit bunches (FFB), and therefore, both use the same mature area. The MPOB has official figures for both the CPO yield and the PK yield. One can estimate the average amount of mature area in production as production and yield data are available. Using the yield figures to estimate mature area gives inconsistent results. Area estimates using CPO yield differ from the estimates using PK yield prior to 1984. In addition, for most of the 2000s, the official MPOB figures imply that nearly 100 % of all planted land was in production, while the official MPOB figures for mature area at the end of the year show that this is implausible. Appendix 1 explains these inconsistencies further and shows an alternative estimation of mature area in production for all years in more detail.

To get a more consistent, and thereby more plausible, estimates of oil yield, I use yearly CPO production and end-of-year mature area data, which are the same for 1975-2011, regardless of whether FAO or MPOB figures are used. For the years 1961-74, production and mature area data are available from the FAO, which are broadly similar to earlier PORLA publications. Figures for the 1950s are estimated using data from Gopal (2001), and are the least accurate. The yield figures for the 1950s are therefore those with the highest degree of uncertainty. To get a more consistent measure of land used in production, I use the amount of mature land at the end of each year divided by two as shown in equation (3).

$$\text{Mature Area Measure}_{\text{t}} = \frac{\text{Mature Area End of Year}_{\text{t}} + \text{Mature Area End of Year}_{\text{t}-1}}{2} \qquad (3)$$

If mature land is relatively evenly used during the year, it would reflect approximately average mature area used. The oil yield is the CPO production divided by the mature area measure as shown in equation (4):

$$\text{CPO Yield}_t = \frac{\text{CPO Production}_t}{\text{Mature Area Measure}_t} \qquad (4)$$

Figure 3 presents the results as five-year moving averages.

[INSERT FIGURE 3 HERE]

The results show that the official MPOB oil yield figures were probably too optimistic in the 1980s and too pessimistic in the 1990s. Taking the estimated figures, the oil yield increased from 1.4 mt/ha in 1950 to 2.3 mt/ha in 1960, and even further to 3.7 mt/ha in 1975; several authors, among them Gopal (2001 p.125), report similar figures. There has also been a considerable increase in long-term yields in the period since the mid-1970s. However, the increase was slow up until the mid-1990s. It is important to analyse the potential reasons for this pattern. To examine the underlying process, I divide the production process into its two stages; figure 4 shows a rough schema of this two-stage process.

[INSERT FIGURE 4 HERE]

The productivity of crude palm oil can therefore be divided into two components as shown in equation (5a), with equation (5b) showing the same two components defined:

$$\frac{\text{Yearly CPO Production}}{\text{Average Mature Area}} = \frac{\text{Yearly Fresh Fruit Bunches Production}}{\text{Average Mature Area}} \times \frac{\text{Yearly CPO Production}}{\text{Yearly Fresh Fruit Bunches Production}} \qquad (5a)$$

$$\text{Oil Yield} = \text{FFB Yield} \times \text{Oil Extraction Rate (OER)} \qquad (5b)$$

To calculate these separate ratios, I had to make some assumptions. Time-series on fresh fruit bunch production suffer from a lack of time consistency as the collection of official data was changed in 1989. The Department of Statistics and the MPOB used different ways of collecting the data, thus, the time series are not comparable. Therefore, I used the FAO time-series on fresh fruit bunch production as these are consistent over time. For estimating the Oil Extraction Rate, the preferred measure is FFB processed and not FFB produced, as some of the FFBs are used for seed production. However, the difference between the two is small and I assumed that the relative share was constant over time. The results are shown in figure 5.

[INSERT FIGURE 5 HERE]

The results show that the growth in the yield of fresh fruit bunches (FFB) is the main contributor to the growth in the oil yield. FFB yield grew fast in the three short periods, 1963-69, 1975-81 and 1999 until the present. These 'leaps' were followed by more modest growth. The most relevant 'leap' for the topic of the paper is the 1975-81 one. The oil extraction rate (OER) contributed to the growth in oil yields from 1963 to 1975, but then entered a period of long-term decline, which lasted until the mid-1990s. Since 1995, the OER has again increased, but has still not come back to the levels of the mid-1970s. If true, it would imply that the main driver for increasing oil yields were productivity improvements at the plantation level. It would also imply that mill productivity held oil yields back.

To find the reason for the increase in oil yields, one has to find the reason for an increase in FFB yields. One potential reason is the increased amount of palm oil research. Several palm oil companies improved their research through the creation of the Oil Palm Genetics Laboratory.[17] In addition, the Malaysian Department of Agriculture launched a research exchange programme with West Africa (Gopal 2001). The most important technological change has been the improvement of the palm trees through the introduction of new species. The introduction of the DxP variety in the late 1960s and early 1970s, which led to more FFB per hectare, is probably the main reason behind the large leap in FFB yields from 1975 to 1981. The DxP variety of oil palm quickly replaced the less efficient DxD and other oil palm species. Since it takes three years from a tree is planted until it reaches harvesting maturity, and a further five years for the highest yield, one would expect yields to increase approximately eight years following the planting of a new DxP tree. There is a lagged correlation between the share of DxP palm trees and the increase in FFB yields eight years later. Data from the Department of Statistics (1969-88) show that plantations that have the DxP variety of oil palm trees have a higher yield than plantations with a different palm oil species. However, there are too few observations, and a large selection bias issue meaning that the regression must be interpreted with caution.

A second reason for improvements in FFB yields is the increased productivity in the government schemes. The private plantations have the best FFB yield. Government schemes, sometimes called organized smallholders, have a lower FFB yield than private plantations. As mentioned previously, the Federal Land Development Authority (FELDA) was the largest

[17] See for instance Kajisa *et al.* (1997).

government scheme in Malaysia (Simeh and Ahmed 2001, other public schemes accounted for a further 16 % of total planted area in 1990). FELDA increased its ownership share of oil palm planted area from less than 5 % in 1970 to around 30 % in 1990 (Fold 1994 p.76). Plantations expanded on good soil, and often shifted from rubber to palm oil. FELDA expanded on virgin soil, often considered of 'secondary suitability' in terms of soil quality and topography. FFB yields of the FELDA programme increased from 13.9 FFB per ha in 1975 to 18.1 FFB per ha in 1985 (DoS various years). Private estates only managed an increase from 18.0 to 18.6 FFB per ha the same years. FELDA's improvements in management and the private incentives for smallholders that took part in the programme probably led to the increase in FFB yields. For more on FELDA see Fold (2000).

The oil extraction rate (OER) has not shown clear progress for the period as a whole. The major reason mentioned for the lack of increase in OER is that FFBs do not have a proper degree of ripeness, which lowers OER (Chan and Lee 1993 p.11). One potential reason for this lack of ripeness is the high competition among mills, especially those without their own plantation. In 1988, 45 mills were located on estates and 58 mills were owned by estates. The remaining 119 mills are 'independent' in the sense that they are owned by smallholders or (local) state organisations or linked to comparatively small private estates (Fold, 1994 p.76). Mills that do not have their own plantations are fully 'supply-dependent'. An estimate made by Thiran (1984) claims that 29 of 171 mills in 1981 were fully 'supply-dependent'. The competition, coupled with the pressure to increase production, might have caused a decline in harvesting standards and the quality of FFBs. Another reason for the lack of ripeness has been the increasing shortage of workers at plantations (Corley and Tinker 2015). This meant that detached FFBs are lying on the ground too long before being transported to mills.

Large private firms owning both plantations and mills in general have higher OERs than the industry average. Chang *et al.* (2003 p.28) shows that the OER is highest for plantation-based mills. The 'supply-dependent' mills came out second, with the government mills having the lowest OER. This might be the result of (i) better labour saving technologies at plantations; (ii) private research which is more directed at firm-specific problems and therefore more likely to be relevant for the firm; and (iii) a tighter integration between plantations and mills, meaning that there are better routines to get FFBs quickly to the mills, thereby increasing their ripeness. However, the OER in private plantation firms, despite being higher, did have the same trends as the rest of the industry, see for instance Gan *et al.* (1993) for Sime Darby; Lee and Shawaluddin (1993) for Golden Hope; and Toh and Tan (1993) for United Plantations.

Labour and multifactor productivity

Since plantations are labour-intensive, labour productivity has special importance. Employment data are taken from 'The Oil Palm, Coconut and Tea Statistics Handbook' published annually by the Department of Statistics. The data from the Department of Statistics show end of year employment for 1969-88. Having only one observation per year could potentially be problematic because of the seasonal nature of production. However, the correlation between annual production and employment in December is high, which makes the indicator plausible as I am more interested in trends than levels.

To analyse the labour productivity for the period 1969-88, I estimate two labour productivity measures shown in equations (6) and (7):

$$\text{Labour Productivity Plantation}_t = \frac{\text{Fresh Fruit Bunch Production}_t}{\left(\frac{\text{Employment End of Year}_t + \text{Employment End of Year}_{t-1}}{2}\right)} \quad (6)$$

$$\text{Labour Productivity Mill}_t = \frac{\text{Crude Palm Oil Production}_t}{\left(\frac{\text{Employment End of Year}_t + \text{Employment End of Year}_{t-1}}{2}\right)} \quad (7)$$

To estimate the input, the employment at the end of each of two successive years is added and divided by two. If work was even during the year, these figures would yield approximately average employment. Regardless, the figures still yield a good comparison over time as the figures are consistent. The input estimation measure for employment is similar to the input measure for land for oil yields. In addition, I had to adjust the data to make sure they were consistent over time. Workers were categorized into (i) Directly employed; and (ii) Contract workers. While the share of directly employed on plantations was available for the whole period, the share of contract workers employed on plantations was only available for 1979-88. Therefore, the share of contact workers employed on plantations and those employed in mills in the period 1969-78 had to be estimated using the trend in the share 1979-88. Therefore, the share of contact workers employed on plantations and those employed in mills in the period 1969-78 had to be estimated using the trend in the share 1979-88. It is important to stress that the results do not hinge on the assumptions that the difference in the relative share of contract workers is small. In addition, the figures did not change noteworthy when re-calculated using only direct employed workers. Appendix 2 shows the calculation and data issues more extensively.

The first labour productivity measure is for the plantations. As the employment figures were only for plantations in Peninsular Malaysia, I excluded FFB production from Sabah and Sarawak, as well as from government schemes. The production data for FFB is the same as for FFB yields, from the FAO (2014), adjusted to make sure that the production figures were only for Peninsular Malaysia plantations. For more details on the estimations, see appendix 2.

The evidence indicates that labour productivity increased strongly for plantations (see figure 6). The results are also consistent with Davidson (1993) who reported increased labour productivity of the Unilever Plantations from 1951 to 1991. Better equipment might explain the increase in labour productivity meaning that capital per worker increased. However, the mechanisation of production of palm oil first started in the 1980s. Anecdotal evidence from the 1970s indicates that there was no large increase in the capital per worker in this decade. Company records from United Plantations Berhad (1975-2009) show no clear trends in the capital at plantations. The problem is that these records include capital invested in mills and refineries, and these explain the large ‘leaps’ in the records. The trend apart from these ‘leaps’ is non-increasing. Figures from the Department of Statistics indicate that real capital per worker was actually decreasing. It is therefore unlikely that an increase in capital caused the increase in labour productivity. The evidence indicates that better organisation and improvements in management probably were the keys to increasing productivity. Mature land per worker in 1970 was 3.3 ha; by 1988, this figure had increased to 8.8 ha. It is not possible to cover an increasing land area without an improvement in the organisation at the plantations.

[INSERT FIGURE 6 HERE]

The labour situation does deserve a special comment, since the 1980s started to see the first signs of problems with labour shortage. A decade earlier, the earlier mentioned New Economic Policy was intended to increase employment opportunities for Bumiputera in rural areas Khera (1976 pp.29-37). The labour-intensive palm oil plantations were suited for this purpose as it provided employment and income possibilities for the poorest. However, in the 1980s following the introduction of manufacturing free trade zones and the higher wages offered there, Malaysians became increasingly unwilling to work on plantations. This created a labour shortage in the palm oil industry, which is a chronic problem for the industry since the 1980s, refusing to go away despite attempts to raise labour productivity and mechanisation. Since 1986, the inflow of foreign workers, especially from Indonesia, is meeting the palm oil industry's need. For the labour constraints in the plantation industry, see Amatzin (2006) and Corley and Tinker (2015).

For plantation mills, labour productivity increased from 1970 to 1986 (see figure 10). The problem is that plantation mills are unlikely to be representative for mills in general. Figure 7 shows that the share of mills that are located on plantations was a declining share of overall mills, declining from 58 % in 1970 to 17 % in 1988. Chang *et al.* (2003 p.28) shows that plantation mills are more productive, as the oil extraction rates differ between plantation types. Less data are available for mills compared to plantations, so no quantitative assessment on the causes of the increase in labour productivity is possible. In addition, mills are capital-intensive and labour productivity is therefore not likely to be as important as for plantations.

[INSERT FIGURE 7 HERE]

Concluding the productivity analysis, both oil yield and labour productivity have increased. In appendix 3 a multifactor productivity is estimated for palm oil plantations, and showing that productivity increased when taking both land and labour into account. Unreported cost estimates, using real cost data, also shows an increased cost effectiveness, meaning that costs per metric tonne CPO has decreased since the 1970s. These results are internally consistent and tells us that productivity at the plantation level did increase in the 1970-1990 period. As labour and land are the major input factors, the long-term competitive position of the Malaysian palm oil industry in the world market is highly dependent on the relative costs of labour and land (Corley and Tinker, 2015).

The role of plantations in the establishment of the refineries

The results of the previous section show that productivity, measured in various ways, probably did increase at the plantation level. The only productivity measure considered here is oil yield as the quality of the data is better than for other productivity measures. Oil palm is the most profitable vegetable oil crop, as shown in table 3. If the palm oil sector had the same oil yield in 2007 as in 1963, it would still be the highest among all vegetable oils. This begs the important question: was the increase in palm oil productivity important for the establishment of the palm oil refineries, or would a mere increase in production have been sufficient?

[INSERT TABLE 3 HERE]

The main relationship between plantations/mills and refineries is that crude palm oil is the major input of the refinery sector. The main product of the palm oil refineries are the exports of processed palm oils (PPO). To test how plantation productivity affected the palm oil refineries, the relationship between plantation productivity and processed palm oil exports is tested. The time series used are yearly observations for the period 1975-2010. Both time series are I(1) when using augmented Dickey-Fuller tests and the PP unit root tests to test for stationarity.[18] The relationship between the two time-series was found to be co-integrated, meaning that the linear combination of plantation productivity and PPO exports is a I(0) process, meaning a stationary process.[19]

To test the long-run relationship a dynamic OLS estimation is used to estimate a single cointegrating vector using the Stock and Watson (1993) model with Newey-West standard errors to correct for autocorrelation.[20] The relationship tested is:

$$\mathrm{PPO_t} = \beta_0 + \beta_1 \mathrm{Prod_t} + \sum_{j=-q}^{p} \gamma_j \, \Delta \mathrm{Prod_{t-j}} + u_t \qquad (8)$$

Here PPO is the exports of processed palm oils measured in million metric tonnes which uses the same sources as the earlier the time series in figure 2.[21] $Prod$ are the newly estimated productivity figures using CPO in metric tonnes per mature area using equation (4) measured in percentage points, see also appendix 1. The lead and lags of $\Delta Prod$ are included to make the stochastic error term independent of previous values. The terms q and p describe the number of lags and leads respectively. The coefficient β_1 is the long-run relationship between the productivity of the palm oil plantations and the amount of processed palm oil exports, showing the increase in PPO exports if productivity would increase by 1 percentage point.

The results are shown in table 4. The three specification show different lags and leads, as the sample size is small the maximum number of lags and leads chosen was 2. The results indicate that plantation productivity was significantly correlated with increased processed palm oil exports. According to estimation (3), an increase in productivity of 1 percentage point would

[18] The augmented Dickey-Fuller test is based on Dickey-Fuller (1979) whilst the PP unit root test is based on Phillips and Perron (1988). As the sample size was small, only two lags were used in the ADF test.
[19] The Engle-Granger test for co-integration was used and the results were at the 5 % level of significance.
[20] The method employed is similar to Bae (2010).
[21] The export figures should preferably be in logarithms, however, the logarithm of processed palm oil exports was a I(0) stationary process, meaning it could not be used in an co-integrating relationship.

increase processed palm oil exports by 11.86 million metric tonnes. The size of the coefficient compared to actual size of the PPO exports indicates that only a small increase in productivity would lead to a sizable increase in PPO exports. The results strongly indicate that there is a long-run structural relationship between plantation productivity and the export of PPO. These results are intuitive as the main competitive advantage of the Malaysian refinery sector is the cheap supply of crude palm oil. In fact, crude palm oil constituted more than 90 % of the material and input costs of refineries (Gopal 2001). The increase in productivity was therefore probably crucial for the establishment of the refinery sector, for four important reasons.

[INSERT TABLE 4 HERE]

First, the increased cost efficiency meant that crude palm oil lowered the input costs for the refineries, both for those refineries that produced their own crude palm oil and those that purchased it on the market. These increases in productivity of plantations probably allowed for a long-term decline of domestic real palm oil prices from 1975 to 1990, which is highly statistically significantly correlated with oil yields.[22] The government, through the export tax on crude palm oil created made cheap crude palm oil available for Malaysian refineries as crude palm oil prices in Malaysia were lower than for the world market, see figure 8.

[INSERT FIGURE 8 HERE]

Obviously, the industrial policy in promoting the refinery sector was only the starting point as the sector experienced a strong learning-by-doing. According to Gopal (2001), the refineries increased their competitiveness becoming internationally competitive during the 1980s. Costs were binding for the palm oil refineries; the evidence coming from two restructuring processes (Fold 1998 pp.401-402). In the early 1980s, a number of Malaysian palm oil refineries went bankrupt as there was a restructuring period following a period of overcapacity. At the end of the 1980s and early 1990s, there was a second and far more severe crisis. This crisis coincided with an increase in crude palm oil prices, as figure 11 shows, which increased input costs, indicating that these costs were binding for the refinery sector. Government support alone did therefore not guarantee the survival of the palm oil refinery sector. Food processing industries in most countries receive government support and this

[22] Fry (1998) also noted the long-term declining price trend in real crude palm oil prices in the late 20th century. However, increasing demand for biofuels led to an increase in prices after 2000 (Corley and Tinker 2015).

support is therefore an important competitive advantage. Government support is a necessary but insufficient condition for food processing companies.

The second, and perhaps more important reason, is that the increased productivity of plantation allowed an increase in supply of crude palm oil (CPO). Malaysian refineries had a high dependence on palm oil as a major input, having a lower degree of substitution than of other vegetable oils compared to European rivals. As a thought experiment, if the oil yield had remained at its 1960 level of roughly 2.3 CPO per mature area; the production of CPO in 1990 would have been more than two millions metric tonnes (around 35.6 %) less than the actual output.[23] Given that virtually all of the crude palm oil was being processed at the refineries, this would have hampered the sector's development. One of the main problems during the establishment years for the refinery sector was idle capacity as supplies could not expand rapidly enough, which were costly given the high degree of fixed costs. Figure 10 illustrates this point by estimating the capacity utilisation ratio using the 1960 oil yield rather than the actual one, all other things being equal. Obviously, all things would not have been equal as the profitability of both palm oil plantations and refineries would have been significantly less, meaning that investments would be less as well. This would have allowed for a slower expansion of the industry given the lack of economies-of-scale and considerable learning-by-doing. The obvious alternative, the import of crude palm oil from other countries, such as Indonesia or the two main African palm oil producing countries would not have been feasible in the late 1970s and early 1980s. These countries would not have been able to increase supply given the inelastic nature of palm oil supply, and the quality of the crude palm oil would have been far less than was needed for the refinery industry.

[INSERT FIGURE 9 HERE]

A third reason is that inputs were becoming increasingly scarce. This goes especially for labour. The increase in labour productivity allowed an increase in production in excess of what otherwise would have been possible. Time-series on employment by the Department of Statistics (2015) indicate that labour productivity has not increased since 1986. The reason is that Malaysian labour increasingly refused to work on plantations and went to better-paid jobs in the manufacturing sectors. Increasingly, the palm oil sector became dependent on foreign labour, especially from Indonesia. However, even if labour productivity probably did not

[23] Same sources as for the productivity analysis.

increase by much since 1986, it also did not decrease. Based on FAO figures of fresh fruit bunch production and time-series data on employment from the Department of Statistics, the FFB per employment ratio increased from 51.8 in 1969 to a high of 241.9 in 1989, and has since been relatively stable. In 2006, the figure was 228.3 tonne FFB per employed worker.

The final reason is that the increase in productivity allowed an expansion of the output of mills. The technological development at the mills was important for the competitiveness of the palm oil sector as the quality of crude palm oil increased (PORAM 1990 and Fold 1994 p.77). This increased quality reduced operating costs for refineries and meant that processed palm oil had a higher degree of quality. Increased controls were vital for this process to occur (Fold 1994 p.77). Even the smallest of the Malaysian refineries have established their own laboratory facilities to ensure the quality of final products (Maycock 1989).

Plantation productivity therefore does seem to have been an important contributing factor to the rise of the refineries in Malaysia. As previous literature claims, industrial policies have played an important role in the establishment of the refinery sector, which has developed into international competitive industry that is far from socially unprofitable endeavour (Gopal, 2001). The current paper finds that the increase in plantation productivity most likely was an important contributing factor to the success of the industry. Most likely, the industrial policy would have been less successful or might even have failed if plantation productivity had not increased.

Conclusion

This paper found that the official productivity measure, the oil yield (metric tonnes crude palm oil per hectare), probably has understated the true extent of the productivity growth at palm oil plantations. As the official oil yield figures were inconsistent, new estimates indicate that there has been a considerable increase in oil yields over time. The main source of this increase has been the increase in fresh fruit bunches per hectare, and not the oil extraction rate. Estimates of labour productivity also show a clear increase in productivity levels consistent with oil yield.

The main purpose of the paper was to analyse the link between the productivity increase mentioned above and the establishment of the palm oil refinery sector. The main finding is that the increase in productivity most likely was a strong contributing factor for the success of the refinery sector. As Gopal (2001) mentioned, the main competitive advantage of the Malaysian palm oil refineries was the access to large supplies of crude palm oil to below world market prices. Without the productivity increases at the planation level, less crude palm oil would have been produced and prices would most likely have been higher hampering the growth of the refinery sector. It also means that the industrial policy towards the Malaysian palm oil sector would most likely have had less of an impact without the increase in productivity.

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Appendix 1: Estimating new yield figures

Stage 1.1: Estimating the Mature Area

To assess the actual oil yield, one has to assess the sources and the collection methods. The oil yield measures the amount of crude palm oil in tonnes per mature area in hectare per annum. Two agencies collected the official data from 1961 until present:

- 1961 to 1988: Department of Statistics of Malaysia (DoS) collected the data, mainly through annual surveys
- From 1989 until the present, the Palm Oil Registration and Licencing Authority (PORLA) had the responsibility for data collection. In 1998, PORLA merged with two other institutions to form the Malaysian Palm Oil Board (MPOB)

Palm oil fruits, fresh fruit bunches, are used to produce a number of different products; the two major ones are crude palm oil and palm kernel, as illustrated in the figure appendix 1.1:

[INSERT FIGURE APPENDIX 1.1 HERE]

To assess the productivity, the Malaysian Palm Oil Board (MPOB) uses two land productivity measures:

$$CPO\ Yield = \frac{Yearly\ CPO\ Production}{Average\ Mature\ Area\ in\ Production\ During\ the\ Year} \qquad \text{(A1.1)}$$

$$PK\ Yield = \frac{Yearly\ PK\ Production}{Average\ Mature\ Area\ in\ Production\ During\ the\ Year} \qquad \text{(A1.2)}$$

The MPOB publishes time-series, starting in 1975. Figures available include the CPO yield and the PK yield, along with yearly production of CPO and PK. The only figure not published, which features in the formula above, is the average amount of mature area used in production that specific year. However, this information can be easily obtained by re-arranging the above two expressions:

$$Average\ Mature\ Area_t = \frac{CPO\ Production_t}{CPO\ Yield_t} \qquad \text{(A1.3)}$$

$$Average\ Mature\ Area_t = \frac{PK\ Production_t}{PK\ Yield_t} \quad \text{(A1.4)}$$

Since the average mature area to produce crude palm oil and palm kernel is the same, equations A1.3 and A1.4 should yield the same result. I attempted to estimate the average mature area in production using these two equations in table appendix 1.1:

[INSERT TABLE APPENDIX 1.1 HERE]

The differences in average mature area, using the two formulas, were large, especially for the period up until 1983 as illustrated in figure appendix 1.2:

[INSERT FIGURE APPENDIX 1.2 HERE]

As an alternative, one could estimate the approximate mature area used by dividing the mature area at the end of year t and the mature area at the end of year t-1:

$$Mature\ Area\ Measure_t = \frac{Mature\ Area\ End\ of\ Year_t - Mature\ Area\ End\ of\ Year_{t-1}}{2} \quad \text{(A1.5)}$$

The MPOB published time-series data on the mature area at the end of the year. I have used this somewhat crude measure to compare it with the other two estimates of productivity in figure appendix 1.3:

[INSERT FIGURE APPENDIX 1.3 HERE]

According to figure appendix 1.3, the mature area estimates using equations A1.3 and A1.4 are internally inconsistent up until 1983, but have followed each relatively closely since then. However, from 1994 and onwards, equation A1.5 gives a lower estimate of mature area than equation A1.3 and A1.4. This is puzzling, since all the data used come from the same source, namely the MPOB. If true, the figures from 1994 and onward would imply that area considered mature during the production year, is immature at the end of the year. This is plausible for a limited number of years, since an area might need to be re-planted towards the end of the year. However, as oil palm trees take approximately 3 years to mature, the figures could only explain the deviation for 2-3 years at most, while the figures above show that this process then must have occurred 17 years in a row. This is highly unlikely, and is therefore dismissed, which means that equation A1.3 and A1.4 yield implausible estimates for mature area in production. In addition, the increase in mature area using A1.5 shows a smoother trend than equations A1.3 and A1.4. This implies that the trend using A1.5 is more plausible.

The official yield figures, from which A1.3 and A1.4 are derived, is therefore inconsistent. More evidence comes from figure appendix 1.4, which seems to indicate unrealistically large fluctuations in the average mature area using the official figures. In addition, if the official figures are true, then the share of land in production has been close to 100 % during the year since 2000, but between 80-85 % at the end of the same years. In conclusion, despite the mature area measure derived by using equation A1.5 is a simple and somewhat crude, it provides a more consistent estimate of mature area used in production than do the first two equations derived from the official yield figures. To re-estimate the oil yield, I therefore use the mature area measure using equation A1.5.

[INSERT FIGURE APPENDIX 1.4 HERE]

Stage 1.2: Estimating the Oil Yields

To construct the oil yields, production data on crude palm oil (CPO) and mature area 1975-2011 are from MPOB (2015). Production data on fresh fruit bunches (FFB) presented a problem as the Department of Statistics, which collected palm oil data up until 1988, reported widely different figures than PORLA/MPOB did following 1989 indicating a measurement change. To avoid internal inconsistency, all FFB production figures from 1961-2011 are from the online FAO (2014) database. Figures for the period 1950-60 are uncertain. The doctoral thesis of Gopal (2001) reported production and oil yield figures for 1950 and 1960, and using these figures, I estimated mature land in these two years. Production and mature area data for 1951 to 1959 are extrapolated separately and must therefore be interpreted with caution. Appendix 1.2 presents the data.

[INSERT TABLE APPENDIX 1.2 HERE]

Using the CPO production and the mature area figures from table appendix 1.2, I estimate two separate oil yields:

$$CPO\ Yield_t = \frac{CPO\ Production_t}{Mature\ Area\ End\ of\ Year_t} \quad \text{(A1.6)}$$

$$CPO\ Yield_t = \frac{CPO\ Production_t}{\left(\frac{Mature\ Area\ End\ of\ Year_t + Mature\ Area\ End\ of\ Year_{t-1}}{2}\right)} \quad \text{(A1.7)}$$

The results, from these two equations are compared with the official oil yield in table appendix 1.3.

[INSERT TABLE APPENDIX 1.3 HERE]

The two components of the oil yield, the FFB yield and the Oil Extraction Rate (OER) are given by:

$$Oil\ Yield = FFB\ Yield \times Oil\ Extraction\ Rate\ (OER) \quad \text{(A1.8)}$$

$$\frac{CPO\ Production}{Mature\ Area} = \frac{FFB\ Production}{Mature\ Area} \times \frac{CPO\ Production}{FFB\ Production} \quad \text{(A1.9)}$$

Using the FFB production, CPO production, and the different measures of mature area, I have estimated the separate components in table appendix 1.4.

[INSERT TABLE APPENDIX 1.4 HERE]

Appendix 2: Labour productivity

Data on employment is available for 1969-1988 in the Department of Statistics '*The Oil Palm, Coconut and Tea Statistics Handbook*'. The main limitation of the data is that data is only available for plantations for Peninsular Malaysia, and therefore the productivity measures are only measured for a part of the plantations. The average annual response rate is around 75 %, with the lowest response rate being two-thirds for two separate years.

For the years 1969-1978, information is available on three categories: (1) Directly employed; (2) Contract workers; and (3) Other workers. The first category consists of (a) Administrative staff; (b) Estate workers; and (c) Mill workers. For the years 1979-1988, the third category, (3) Other workers, is incorporated in the figures for various plantation staff. In addition, contract workers for 1979-1988 are subdivided into (a) Estate workers and (b) Mill workers.

To make the figures consistent, I made some modifications. The reason for these modifications is that a small share of the workers are classified differently in the two periods. To be able to compare the data, I had to make three adjustments. First, I added the category (3) Other workers to the (1b) Directly employed estate workers for 1969-1978. Second, I included a residual category called 'unpaid family workers, working proprietors and partners' in the (1b) category for 1979-1988. Finally, as the estate and mill shares for contract workers were unavailable for 1969-78, I estimated these. To estimate the respective shares of estate and mill workers, I used the 1979-1988 data. Estimating the share of the estate workers as a share of total workers from 1979 to 1988 yields the following trend as illustrated in figure appendix 2.1

[INSERT FIGURE APPENDIX 2.1 HERE]

To estimate the share from 1969-78 I assume the same linear trend. The linear trend gave the highest R^2 and is found appropriate as the period estimated is short. It is important to emphasise that the results in this paper do not hinge on these assumptions, since the results are the same if only directly employed figures were employed, whether all contract workers were assumed to be working on plantations or using these estimated figures. The real figures and the estimated ones are presented in table appendix 2.1:

[INSERT TABLE APPENDIX 2.1 HERE]

The data on employment back to 1969 was only available for the plantations of Peninsular Malaysia. Employment data for Sabah and Sarawak first became available from 1980 and onwards. Therefore, the production and land figures had to be re-adjusted. I therefore deducted the Sabah and Sarawak production quantity of fresh fruit bunches for 1969-1988; and for the mature area 1969-1974, using Department of Statistics data. As the total production and mature area figures included both plantations and government schemes, I had to adjust for that as well. The problem was that FFB production data for government schemes was missing for 1969-1972, while they were available for 1973-1988. Using the 1973-1988 figures, I estimated a linear trend for both production and land as illustrated in figure appendix 2.2. Again, the linear trend gave the highest R^2 and was chosen, as the time-period estimated for was short.

[INSERT FIGURE APPENDIX 2.2 HERE]

The data on employment for mills is only available for those mills that are located on plantations. Data is available for crude palm oil production coming from these mills, and to get a more accurate estimate of the labour productivity of mills, I only use this production figure. I also included data on the share of CPO production coming from mills located on plantations as a share of total CPO production in Peninsular Malaysia. The data used on production and land are presented in table appendix 2.2.

[INSERT TABLE APPENDIX 2.2 HERE]

The employment figures are end of year figures; therefore, I take the averages of the two end of year figures to construct labour input. The labour productivity measures for plantations and for mills are estimated by equations A2.1 and A2.2:

$$Labour\ Productivity\ Plantation_t = \frac{Fresh\ Fruit\ Bunch\ Production_t}{\left(\frac{Employment\ End\ of\ Year_t + Employment\ End\ of\ Year_{t-1}}{2}\right)} \tag{A2.1}$$

$$Labour\ Productivity\ Mill_t = \frac{Crude\ Palm\ Oil\ Production\ Plantation\ Mills_t}{\left(\frac{Employment\ End\ of\ Year_t + Employment\ End\ of\ Year_{t-1}}{2}\right)} \tag{A2.2}$$

For the calculation of labour productivity at the plantation level, I use workers from categories (1a), (1b) and (2a). For the calculation for labour productivity at the mill level, I use workers from categories (1c) and (2b). I also measure the amount of land per employee by estimating equation A2.3:

$$Land\ per\ Employee_t = \frac{\left(\frac{Mature\ Area\ End\ of\ Year_t + Mature\ Area\ End\ of\ Year_{t-1}}{2}\right)}{\left(\frac{Employment\ End\ of\ Year_t + Employment\ End\ of\ Year_{t-1}}{2}\right)} \quad \text{(A2.3)}$$

Table appendix 2.3 shows the estimated labour productivity and land per employee.

[INSERT TABLE APPENDIX 2.3 HERE]

Appendix 3: Estimating multifactor productivity

Multifactor productivity, also known as total factor productivity, is used to measure multiple inputs. The reason for preferring "multi-" rather than "total-" lies in the fact that the latter implies that all factors of production are accounted for, which is seldom the case. The methodology of growth accounting is well-established see for instance Solow (1957) and Ahearn *et al.* (1998).

In the case of the palm oil sector, capital data is as mentioned not of sufficient quality to use in such an analysis. Capital data also suffer from another problem, that it often involves monetary values that might in part be arbitrary, such as the rate of depreciation. In addition, most of the capital used in the palm oil plantations are related to land.

Ignoring the mills, and focusing on plantations, one can estimate a multifactor productivity measure using a simple growth accounting framework in which there are two factors of production; land N and labour, L; which are represented by a Cobb-Douglas production function:

$$Y = F(N, L) = AN^{\alpha}L^{1-\alpha}$$

The production Y in question is the fresh fruit bunches (FFB) as these are for plantations, whilst the unknown productivity term is A. The income share of labour, $1 - \alpha$ is set to 50 % as this approximates the share of wages of total profit for United Plantations (various years). One can obtain the growth rate of productivity by taken the change in logarithm and re-arranging to yield:

$$\Delta \ln A = \Delta \ln Y - \alpha \Delta \ln N - (1 - \alpha) \Delta \ln L$$

Changes in logarithm represents the approximate annual growth. The data used is the same as for appendix 2, from the 1969-1988 in the Department of Statistics '*The Oil Palm, Coconut and Tea Statistics Handbook*'. The main limitation of the data is that data is only available for plantations for Peninsular Malaysia, and therefore the productivity measures are only measured for a part of the plantations. The production data used is the one reported by these plantations, which is the FFB production reported in table appendix 2.2. Data for the mature area for the same plantations are also taken from table appendix 2.2. The labour data is from table appendix 2.1 (sum of categories (1a), (1b) and (1c) as explained in appendix 2). The results are shown in table appendix 3.1:

[INSERT TABLE APPENDIX 3.1 HERE]

As can be seen from table, productivity growth slowed somewhat from 3.0 % 1970-79 to 1.7 % from 1979-88. In relative terms, however, productivity was slightly more important as it contributed to 21.1 % of the growth from 1970-79, while it increased to 22.5 % in from 1979-88. The cause of the decrease in production growth is the decrease in labour growth in the 1980s, with the growth rate of labour falling from 8.7 % in the former period to 2.8 in the latter. It should be cautioned that the labour and multifactor productivity figures rely on data that is less reliable than the land figures as they only cover a segment of the palm oil industry, and should therefore be interpreted with caution.

Table 1: Phases of development in the Malaysian palm oil sector

Phase 1: Colonial times (1875 to 1957)	The introduction of palm oil in the 19th century and its first commercial exploitation from 1917: • Slow growth in crude palm oil production and exports
Phase 2: Promotion of palm oil production (1957 to 1973)	Government promotion of palm oil: Investment and tax incentives • High growth in crude palm oil production and exports
Phase 3: Promotion of refineries (1973 to 1986)	Government promotion of increased value-added: • Investment and tax incentives • Increased institutional support • Export tax on crude palm oil • High growth in crude palm oil production • High growth in processed palm oil production and exports
Phase 4: Promotion of upstream and downstream activities (1986 onwards)	Government promotion of backward and forward linkages: • Investment and tax incentives • High institutional support • Continued high growth of processed palm oil production and exports • Continued high growth of crude palm oil production • Establishment of the oleochemical industry with subsequent high growth

Table 2: Palm Oil Refineries Capacity in Operation in Malaysia 1971-2010

Year	Capacity in operation	Palm oil refineries in operation	Average refinery size in operation	CPO Processed at Refineries/CPO Production
	Million metric tonnes	No.	Million metric tonnes	Percentage
1971	0.08	2	0.04	4 %
1975	0.80	10	0.08	21 %
1980	2.88	45	0.06	95 %
1985	5.35	38	0.14	89 %
1990	10.45	37	0.28	106 %
1995	10.15	41	0.25	100 %
2000	14.60	46	0.32	93 %
2005	17.31	48	0.36	94 %
2010	22.89	51	0.45	93 %

Source: Gopal (2001) Table 4.1 for 1971-1995; and MPOB (2000; 2005) Table 2.14 and MPOB (2010) Table 2.17 for 2000-2010

Table 3: Value per ha (nominal values based three-year average)

	1962-64	1984-86	2006-08
Crude Palm Oil – Malaysia			
Oil Yield*	2.40	3.31	4.29
Price – USD**	237	466	662
Value per ha	569	1,545	2,844
Rapeseed Oil – European Union			
Oil Yield*	0.58	0.90	1.16
Price – USD**	245	467	924
Value per ha	141	421	1,069
Soyabean Oil – USA			
Oil Yield*	0.18	0.17	0.31
Price – USD**	243	499	826
Value per ha	45	85	259
Sunflower Oil – Argentina			
Oil Yield*	0.20	0.47	0.69
Price – USD**	268	535	942
Value per ha	54	251	651

Source: Calculations based on FAO (2014) and MPOB (2011)

*Oil Yield is calculated as the three-year moving average of production (tonnes) per harvested area (ha) using FAO data

** Prices are three-year moving averages of annual average prices in dollar per metric tonne registered on the North West Europe Market

Table 4: Dynamic OLS regression results

	(1) PPO	(2) PPO	(3) PPO
$Prod_t$	10.84***	11.08***	11.86***
	(8.58)	(5.96)	(5.18)
Observations	33	31	29

Note: All results were obtained dynamic OLS. t statistics in parentheses based on Newey-West standard errors with 5 lags, with * significant at the 10 % level, ** significant at the 5 % level, and *** significant at the 1 % level. Constant term, lagged and lead values are not shown. Estimation (1) is for 1 lag and 1 lead, estimation (2) for 2 lags and 2 leads, and estimation (3) for 3 lags and 3 leads.

Table appendix 1.1: Estimated mature area using equations A1.3 and A1.4							
Year	CPO Yield	CPO Production	PK Yield	PK Production	Mature Area Equation A1.3	Mature Area Equation A1.4	$\left(\frac{\text{Equation A1.3}}{\text{Equation A1.4}} - 1\right)\%$
1975	3.66	1,257,573	0.74	232,821	343,599	314,623	9.21 %
1976	3.48	1,391,965	0.71	256,015	399,990	360,585	10.93 %
1977	3.54	1,612,747	0.74	334,791	455,578	452,420	0.70 %
1978	2.95	1,785,525	0.68	367,540	605,263	540,500	11.98 %
1979	3.65	2,188,699	0.79	475,039	599,644	601,315	-0.28 %
1980	3.78	2,573,173	0.81	557,066	680,734	687,736	-1.02 %
1981	3.76	2,822,144	0.79	588,783	750,570	745,295	0.71 %
1982	3.83	3,510,920	0.80	909,918	916,689	1,137,398	-19.40 %
1983	3.43	3,016,481	0.72	834,570	879,441	1,159,125	-24.13 %
1984	4.25	3,714,795	1.19	1,045,579	874,069	878,638	-0.52 %
1985	4.33	4,134,463	1.28	1,211,887	954,841	946,787	0.85 %
1986	4.41	4,542,249	1.28	1,336,263	1,029,988	1,043,955	-1.34 %
1987	3.39	4,531,960	0.98	1,311,218	1,336,861	1,337,978	-0.08 %
1988	3.47	5,027,496	1.01	1,473,288	1,448,846	1,458,701	-0.68 %
1989	3.88	6,056,501	1.15	1,793,690	1,560,954	1,559,730	0.08 %
1990	3.64	6,094,622	1.10	1,844,737	1,674,347	1,677,034	-0.16 %
1991	3.48	6,141,353	1.01	1,785,218	1,764,757	1,767,543	-0.16 %
1992	3.43	6,373,461	0.99	1,874,367	1,858,152	1,893,300	-1.86 %
1993	3.78	7,403,498	1.16	2,266,104	1,958,597	1,953,538	0.26 %
1994	3.43	7,220,631	1.05	2,203,929	2,105,140	2,098,980	0.29 %
1995	3.50	7,810,546	1.08	2,395,588	2,231,585	2,218,137	0.61 %
1996	3.55	8,385,886	1.06	2,488,750	2,362,221	2,347,877	0.61 %
1997	3.63	9,068,728	1.06	2,638,068	2,498,272	2,488,743	0.38 %
1998	3.02	8,319,682	0.88	2,429,468	2,754,862	2,760,759	-0.21 %
1999	3.58	10,553,918	1.03	3,025,690	2,948,022	2,937,563	0.36 %
2000	3.46	10,842,095	1.01	3,162,760	3,133,553	3,131,446	0.07 %
2001	3.66	11,803,788	1.05	3,367,710	3,225,079	3,207,343	0.55 %
2002	3.59	11,909,298	0.98	3,268,635	3,317,353	3,335,342	-0.54 %
2003	3.75	13,354,769	1.02	3,627,235	3,561,272	3,556,113	0.15 %
2004	3.73	13,976,182	0.98	3,661,456	3,746,966	3,736,180	0.29 %
2005	3.80	14,961,654	1.01	3,964,031	3,937,277	3,924,783	0.32 %
2006	3.93	15,880,786	1.02	4,125,124	4,040,912	4,044,239	-0.08 %
2007	3.83	15,823,745	0.99	4,096,989	4,131,526	4,138,373	-0.17 %
2008	4.08	17,734,441	1.05	4,577,500	4,346,677	4,359,524	-0.29 %
2009	3.93	17,564,937	1.01	4,500,683	4,469,450	4,456,122	0.30 %
2010	3.69	16,993,717	0.93	4,292,076	4,605,343	4,615,135	-0.21 %
2011	4.01	18,911,520	1.00	4,706,603	4,716,090	4,706,603	0.20 %

Source: Yield and production figures gathered from MPOB (2012) tables 1.17 and 3.2

Table Appendix 1.2: Production and land data palm oil				
Year	FFB Production	CPO Production	Mature Area End of Year	Mature Area Measure Equation A1-5
1950		54,100	37,832	
1951		57,870	38,058	37,945
1952		61,640	38,283	38,170
1953		65,410	38,509	38,396
1954		69,180	38,734	38,621
1955		72,950	38,960	38,847
1956		76,720	39,185	39,073
1957		80,490	39,411	39,298
1958		84,260	39,636	39,524
1959		88,030	39,862	39,749
1960		91,800	40,087	39,975
1961	500,000	94,846	43,302	41,695
1962	570,000	108,171	46,175	44,739
1963	662,000	125,691	49,073	47,624
1964	647,000	122,913	52,900	50,987
1965	792,000	150,411	59,000	55,950
1966	949,000	189,687	67,400	63,200
1967	1,129,000	225,758	78,500	72,950
1968	1,415,000	282,984	99,100	88,800
1969	1,761,000	352,096	125,400	112,250
1970	2,155,000	431,069	149,900	137,650
1971	2,902,000	580,389	184,000	166,950
1972	3,422,000	718,580	235,100	209,550
1973	3,870,000	812,614	278,300	256,700
1974	4,981,000	1,045,975	329,800	304,050
1975	6,200,000	1,257,573	385,666	363,809
1976	6,500,000	1,391,965	454,009	419,838
1977	7,500,000	1,612,747	521,486	487,748
1978	9,900,000	1,785,525	603,087	562,287
1979	10,700,000	2,188,699	670,299	636,693
1980	12,800,000	2,573,173	777,388	723,844
1981	14,400,000	2,822,144	848,143	812,766
1982	17,900,000	3,510,920	888,619	868,381
1983	15,400,000	3,016,481	1,010,879	949,749
1984	19,500,000	3,714,795	1,072,451	1,041,665
1985	21,400,000	4,134,463	1,201,010	1,136,731
1986	23,100,000	4,542,249	1,360,579	1,280,795
1987	22,800,000	4,531,960	1,373,147	1,366,863
1988	25,300,000	5,027,496	1,530,906	1,452,027
1989	30,600,000	6,056,501	1,672,096	1,601,501
1990	31,000,000	6,094,622	1,746,054	1,709,075
1991	31,500,000	6,141,353	1,826,267	1,786,161
1992	33,200,000	6,373,461	1,890,268	1,858,268
1993	39,700,000	7,403,498	2,020,516	1,955,392
1994	38,800,000	7,220,631	2,144,080	2,082,298
1995	42,200,000	7,810,546	2,243,065	2,193,573
1996	44,030,000	8,385,886	2,353,147	2,298,106
1997	47,670,000	9,068,728	2,513,183	2,433,165
1998	43,840,000	8,319,682	2,638,020	2,575,602
1999	55,000,000	10,553,918	2,856,701	2,747,361
2000	56,600,000	10,842,095	2,941,791	2,899,246
2001	58,950,000	11,803,788	3,005,267	2,973,529
2002	59,546,000	11,909,298	3,188,307	3,096,787
2003	66,775,000	13,354,769	3,303,133	3,245,720
2004	69,881,000	13,976,182	3,450,960	3,377,047
2005	74,800,000	14,961,654	3,631,440	3,541,200
2006	79,400,000	15,880,786	3,703,254	3,667,347
2007	79,100,000	15,823,745	3,764,389	3,733,822
2008	88,672,000	17,734,441	3,915,924	3,840,157
2009	87,825,000	17,564,937	4,075,702	3,995,813
2010	84,965,000	16,993,717	4,202,213	4,138,958
2011	94,557,600	18,911,520	4,281,837	4,242,025

Source: MPOB (2011) table 1.2 (mature area) and 3.2 (CPO production) for 1975-2011; FAO (2014) for FFB production 1961-2011; CPO production and mature area 1961-1974; 1950 and 1960 figures from Gopal (2001) table 3.8 page 125; 1951-1959 extrapolated

Table Appendix 1.3: Oil yields, official and estimated			
Year	Official MPOB Oil Yield	Equation A1.6	Equation A1.7
1950		1.43	
1951		1.52	1.53
1952		1.61	1.61
1953		1.70	1.70
1954		1.79	1.79
1955		1.87	1.88
1956		1.96	1.96
1957		2.04	2.05
1958		2.13	2.13
1959		2.21	2.21
1960		2.29	2.30
1961		2.19	2.27
1962		2.34	2.42
1963		2.56	2.64
1964		2.32	2.41
1965		2.57	2.70
1966		2.88	3.05
1967		3.01	3.20
1968		3.06	3.38
1969		3.01	3.36
1970		3.05	3.34
1971		3.29	3.66
1972		3.33	3.67
1973		3.13	3.42
1974		3.06	3.48
1975	3.66	3.26	3.46
1976	3.48	3.07	3.32
1977	3.54	3.09	3.31
1978	2.95	2.96	3.18
1979	3.65	3.27	3.44
1980	3.78	3.31	3.55
1981	3.76	3.33	3.47
1982	3.83	3.95	4.04
1983	3.43	2.98	3.18
1984	4.25	3.46	3.57
1985	4.33	3.44	3.64
1986	4.41	3.34	3.55
1987	3.39	3.30	3.32
1988	3.47	3.28	3.46
1989	3.88	3.62	3.78
1990	3.64	3.49	3.57
1991	3.48	3.36	3.44
1992	3.43	3.37	3.43
1993	3.78	3.66	3.79
1994	3.43	3.37	3.47
1995	3.50	3.48	3.56
1996	3.55	3.56	3.65
1997	3.63	3.61	3.73
1998	3.02	3.20	3.26
1999	3.58	3.69	3.87
2000	3.46	3.69	3.74
2001	3.66	3.93	3.97
2002	3.59	3.74	3.85
2003	3.75	4.04	4.11
2004	3.73	4.05	4.14
2005	3.80	4.12	4.23
2006	3.93	4.29	4.33
2007	3.83	4.20	4.24
2008	4.08	4.53	4.62
2009	3.93	4.31	4.40
2010	3.69	4.04	4.11
2011	4.01	4.42	4.46

Source: Official MPOB yield gathered from MPOB (2011) table 1.17. The other figures used are data from table appendix 1.2

Table Appendix 1.4: Oil Yield and its separate components

Year	Method 1: End Year Mature Area			Method 2: Mature Area Measure		
	FFB Yield	OER	Oil Yield	FFB Yield	OER	Oil Yield
1961	11.55	0.19	2.19	11.99	0.19	2.27
1962	12.34	0.19	2.34	12.74	0.19	2.42
1963	13.49	0.19	2.56	13.90	0.19	2.64
1964	12.23	0.19	2.32	12.69	0.19	2.41
1965	13.53	0.19	2.57	14.21	0.19	2.70
1966	14.41	0.20	2.88	15.26	0.20	3.05
1967	15.03	0.20	3.01	16.02	0.20	3.20
1968	15.29	0.20	3.06	16.88	0.20	3.38
1969	15.04	0.20	3.01	16.80	0.20	3.36
1970	15.27	0.20	3.05	16.69	0.20	3.34
1971	16.46	0.20	3.29	18.29	0.20	3.66
1972	15.86	0.21	3.33	17.46	0.21	3.67
1973	14.89	0.21	3.13	16.27	0.21	3.42
1974	14.57	0.21	3.06	16.55	0.21	3.48
1975	16.08	0.20	3.26	17.04	0.20	3.46
1976	14.32	0.21	3.07	15.48	0.21	3.32
1977	14.38	0.22	3.09	15.38	0.22	3.31
1978	16.42	0.18	2.96	17.61	0.18	3.18
1979	15.96	0.20	3.27	16.81	0.20	3.44
1980	16.47	0.20	3.31	17.68	0.20	3.55
1981	16.98	0.20	3.33	17.72	0.20	3.47
1982	20.14	0.20	3.95	20.61	0.20	4.04
1983	15.23	0.20	2.98	16.21	0.20	3.18
1984	18.18	0.19	3.46	18.72	0.19	3.57
1985	17.82	0.19	3.44	18.83	0.19	3.64
1986	16.98	0.20	3.34	18.04	0.20	3.55
1987	16.60	0.20	3.30	16.68	0.20	3.32
1988	16.53	0.20	3.28	17.42	0.20	3.46
1989	18.30	0.20	3.62	19.11	0.20	3.78
1990	17.75	0.20	3.49	18.14	0.20	3.57
1991	17.25	0.19	3.36	17.64	0.19	3.44
1992	17.56	0.19	3.37	17.87	0.19	3.43
1993	19.65	0.19	3.66	20.30	0.19	3.79
1994	18.10	0.19	3.37	18.63	0.19	3.47
1995	18.81	0.19	3.48	19.24	0.19	3.56
1996	18.71	0.19	3.56	19.16	0.19	3.65
1997	18.97	0.19	3.61	19.59	0.19	3.73
1998	16.88	0.19	3.20	17.16	0.19	3.26
1999	19.25	0.19	3.69	20.17	0.19	3.87
2000	19.24	0.19	3.69	19.52	0.19	3.74
2001	19.62	0.20	3.93	19.82	0.20	3.97
2002	18.68	0.20	3.74	19.23	0.20	3.85
2003	20.22	0.20	4.04	20.57	0.20	4.11
2004	20.25	0.20	4.05	20.69	0.20	4.14
2005	20.60	0.20	4.12	21.12	0.20	4.23
2006	21.44	0.20	4.29	21.65	0.20	4.33
2007	21.01	0.20	4.20	21.18	0.20	4.24
2008	22.64	0.20	4.53	23.09	0.20	4.62
2009	21.55	0.20	4.31	21.98	0.20	4.40
2010	20.22	0.20	4.04	20.53	0.20	4.11
2011	22.08	0.20	4.42	22.29	0.20	4.46

Source: Calculated using data presented in table appendix 1.2.

Table appendix 2.1 Employment Palm Oil Estates by Number at the End of the Year								
Year	1. Directly employed				2. Contract workers			TOTAL
	(a) Administrative Staff	(b) Estate Workers*	(c) Mill Workers	Total Directly Employed	(a) Estate Workers	(b) Mill Workers	Total Contract Workers	Total Employed
1969	1,554	19,500	1,778	22,832	**10,572**	**574**	11,146	33,978
1970	1,382	21,302	1,877	24,561	**11,264**	**584**	11,848	36,409
1971	1,471	24,517	2,138	28,126	**12,956**	**640**	13,596	41,722
1972	1,545	25,707	2,057	29,309	**17,600**	**827**	18,427	47,736
1973	1,660	28,958	2,013	32,631	**18,335**	**818**	19,153	51,784
1974	1,993	35,329	2,182	39,504	**22,956**	**969**	23,925	63,429
1975	4,300	33,615	2,412	40,327	**24,510**	**976**	25,486	65,813
1976	4,781	35,174	2,608	42,563	**22,427**	**840**	23,267	65,830
1977	5,040	37,537	2,288	44,865	**22,897**	**803**	23,700	68,565
1978	5,819	39,975	2,382	48,176	**24,808**	**812**	25,620	73,796
1979	6,672	41,965	2,606	51,243	27,158	729	27,887	79,130
1980	7,832	44,527	2,760	55,119	27,000	778	27,778	82,897
1981	8,983	45,719	2,836	57,538	27,721	689	28,410	85,948
1982	9,282	43,776	2,847	55,905	27,784	654	28,438	84,343
1983	9,317	43,434	2,683	55,434	24,213	496	24,709	80,143
1984	10,442	43,290	2,725	56,457	29,369	509	29,878	86,335
1985	10,718	43,775	2,764	57,257	32,830	494	33,324	90,581
1986	10,985	42,874	2,755	56,614	30,511	476	30,987	87,601
1987	11,544	42,535	2,760	56,839	34,209	317	34,526	91,365
1988	12,257	43,133	2,680	58,070	37,982	318	38,300	96,370

Source: For the years 1969-1978: Department of Statistics (1973) Table 43; Department of Statistics (1978) Table 45
For the years 1979-1988: Department of Statistics (1983) Table 42; Department of Statistics (1988) Table 10.1
Figures in bold are estimated using the estimated share of estate and contract workers
* For the years 1969-1978: Includes the category 'other workers'; For the years 1979-1988: Includes the category 'unpaid family workers, working proprietors and partners'

Table appendix 2.2 FFB, CPO production and mature area, all figures for plantations located in Peninsular Malaysia

Year	FFB Production (metric tonnes)	Mature Area (Hectare)	CPO Production Mills (metric tonnes)	CPO Production Share Mills on Plantations
1969	1,713,911	104,841	192,585	59 %
1970	1,689,418	114,681	232,318	58 %
1971	2,234,850	137,746	301,385	55 %
1972	2,565,746	176,206	318,237	48 %
1973	2,898,678	190,697	327,667	44 %
1974	3,563,765	220,882	391,531	42 %
1975	4,280,113	248,556	459,814	40 %
1976	4,507,975	299,733	476,094	38 %
1977	5,220,453	334,392	509,685	34 %
1978	7,346,168	373,747	505,011	31 %
1979	7,069,063	408,867	614,137	30 %
1980	7,870,750	449,514	640,369	27 %
1981	8,830,108	483,936	648,348	25 %
1982	10,810,010	525,095	737,172	23 %
1983	9,415,567	601,292	582,059	21 %
1984	12,066,568	645,607	659,938	19 %
1985	13,051,008	703,246	711,288	19 %
1986	13,849,386	784,680	759,063	18 %
1987	13,633,600	774,665	696,453	17 %
1988	15,472,856	896,205	774,990	17 %

Source: The production and mature area figures for FFB are from the same source as in Appendix 1.2 with two deductions.

The mature area for peninsular data for 1975-1988 are from MPOB (2011) table 1.2. The first the deduction by the FFB production (1969-1988) and mature area (1969-74) from Sabah and Sarawak using data Department of Statistics (1974; 1975; 1976; 1977; 1978; 1979; 1980; 1981) Table 51; Department of Statistics (1982; 1983) Table 49; Department of Statistics (1984; 1985; 1986) Table 12.6; Department of Statistics (1987; 1988) Table 12.4; and Department of Statistics (1974) Table 46.

The second deduction is by excluding the share of production and mature area of non-plantations. For data on the plantation share of production and mature area in Peninsular Malaysia I used the Department of Statistics (1973; 1974; 1975; 1976; 1977; 1978; 1979; 1980; 1981) Table 32; Department of Statistics (1982; 1983) Table 30; Department of Statistics (1984; 1985; 1986; 1987; 1988) Table 6.2.

CPO production by mills on estates, and their share, was gathered from Department of Statistics (1969) Table 24; Department of Statistics (1970; 1971; 1972) Table 26; Department of Statistics (1973; 1974; 1975; 1976; 1977; 1978; 1979; 1980; 1981) Table 34; Department of Statistics (1982; 1983) Table 32; Department of Statistics (1984; 1985; 1986; 1987; 1988) Table 6.4.

Table appendix 2.3: Labour Productivity for Plantations and Mills; and Land per Labour Ratio

	FFB Production per Person Employed	CPO Production per Person Employed	Mature Area per Person Employed
1970	52	97	3,3
1971	61	115	3,5
1972	61	112	3,7
1973	62	115	3,9
1974	65	131	3,8
1975	70	141	3,8
1976	72	139	4,3
1977	82	156	5,2
1978	108	161	5,8
1979	97	188	5,9
1980	101	186	6,1
1981	109	184	6,0
1982	132	210	6,6
1983	119	174	7,7
1984	151	206	8,4
1985	153	219	8,8
1986	161	234	9,0
1987	158	221	8,9
1988	170	255	8,8

Source: Calculated with data from tables appendix 2.1 and 2.2

Table appendix 3.1: Multifactor productivity estimate, average annual growth rates				
Years	Production growth	Land growth	Labour growth	MFP growth
1970-1979	14.2 %	13.6 %	8.7 %	3.0 %
1979-1988	7.4 %	8.7 %	2.8 %	1.7 %

Source: Estimated using production, land and labour data from appendix 2.

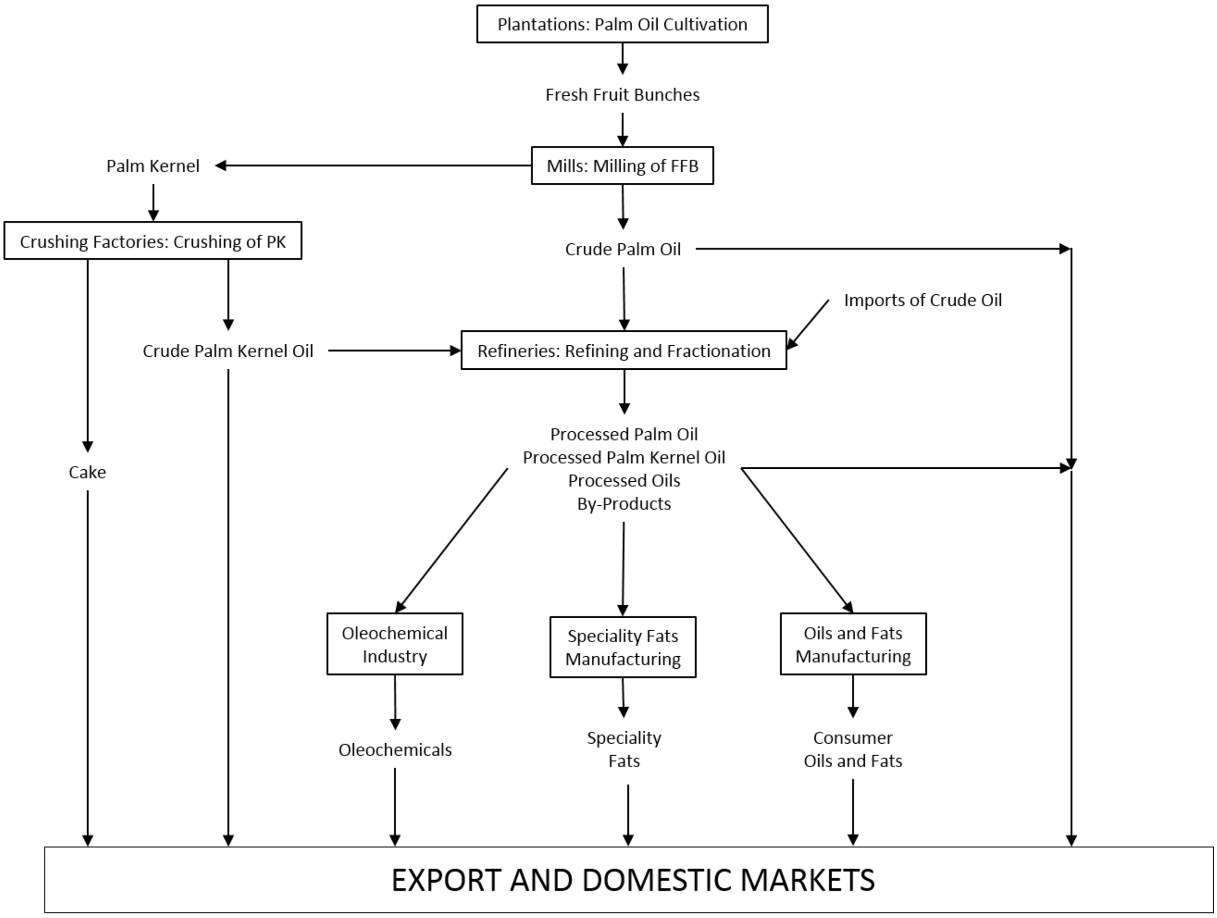

Figure 1: Schematic Summary Malaysian Palm Oil Industry

Source: Gopal (2001 Figure 3.1 p.131)

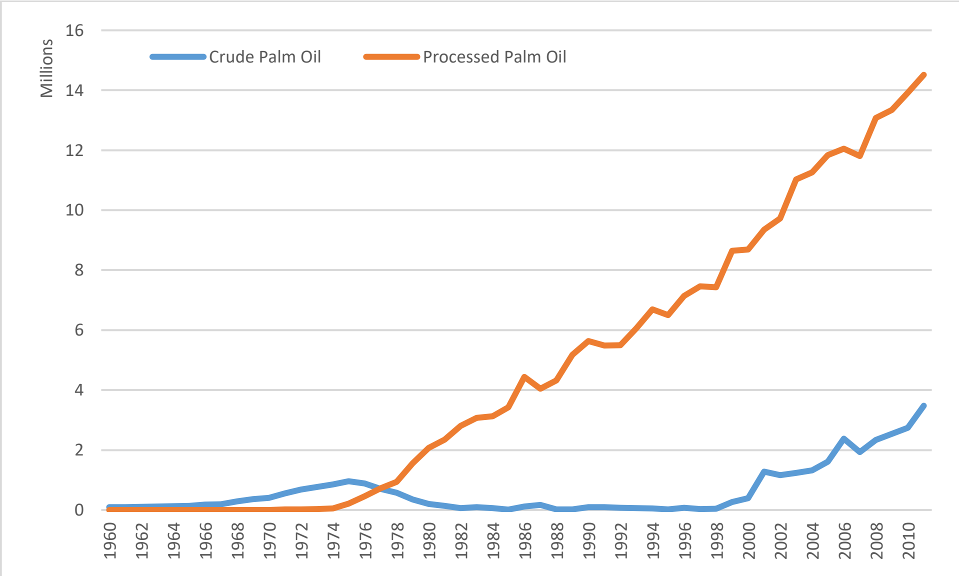

Figure 2: Exports (Metric Tonnes) 1960-2011

Source: Gopal (2001) Table 4.4 for 1960-74; and MPOB (2012) Table 4.1 for 1975-2011

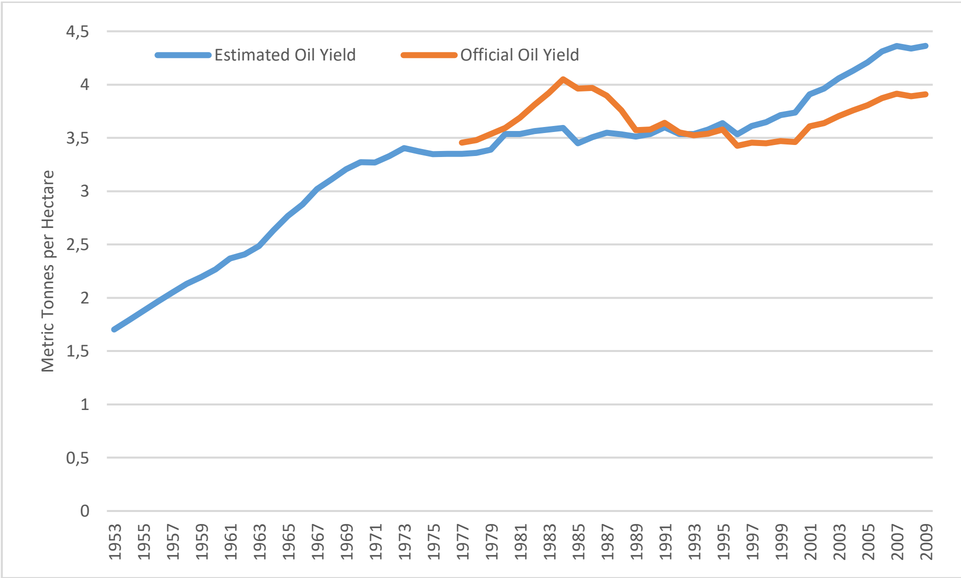

Figure 3: Oil Yield: Crude Palm Oil (metric tonnes)/ Mature Area (ha) 1953-2009 (Five-Year Moving Average)

Note: For sources and a more detailed explanation of the estimation, see appendix 1

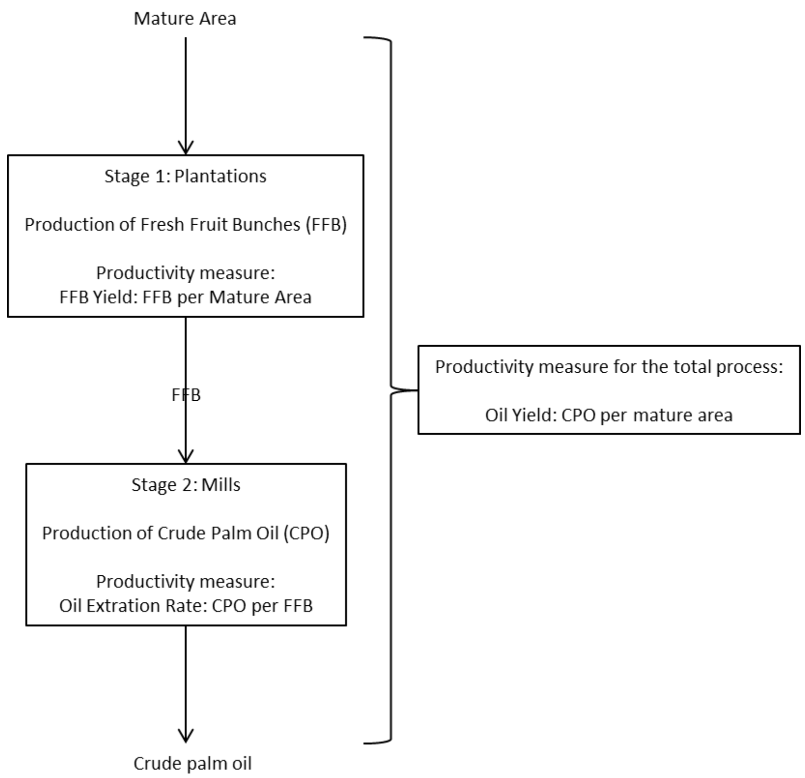

Figure 4: Production process of Crude Palm oil

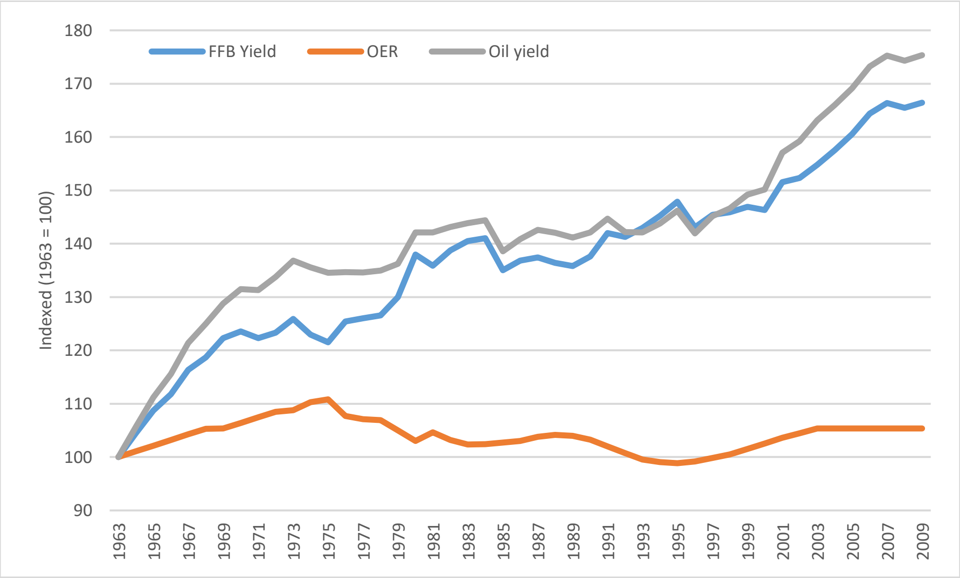

Figure 5: Oil Yield, FFB Yield and OER 1963-2009 (Five-Year Moving Average)

Note: For sources and a more detailed explanation of the estimation, see appendix 1

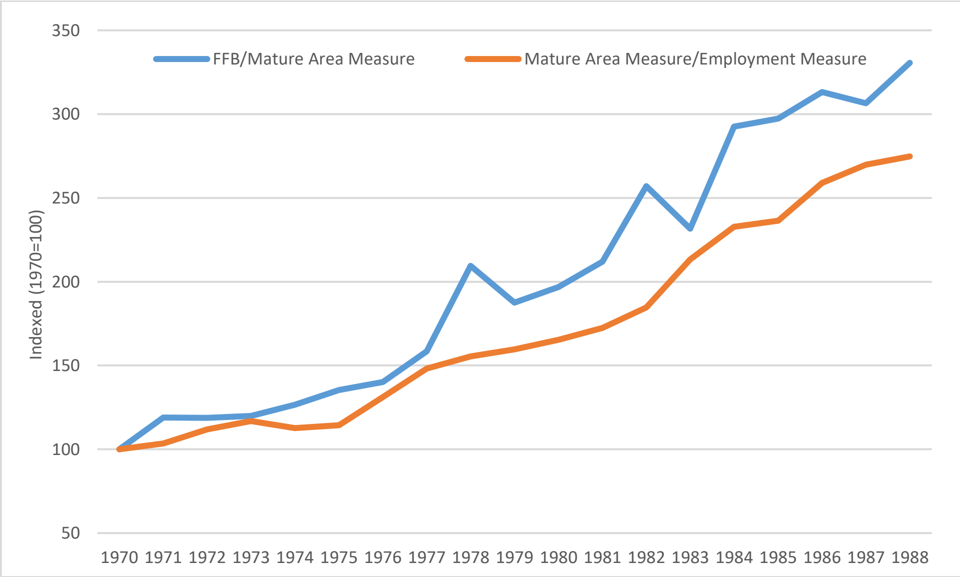

Figure 6: Labour Productivity and Land per Labour Ratio Plantations Peninsular Malaysia 1970-1988 (1970 = 100)

Note: For sources and a more detailed explanation of the estimation, see appendix 2

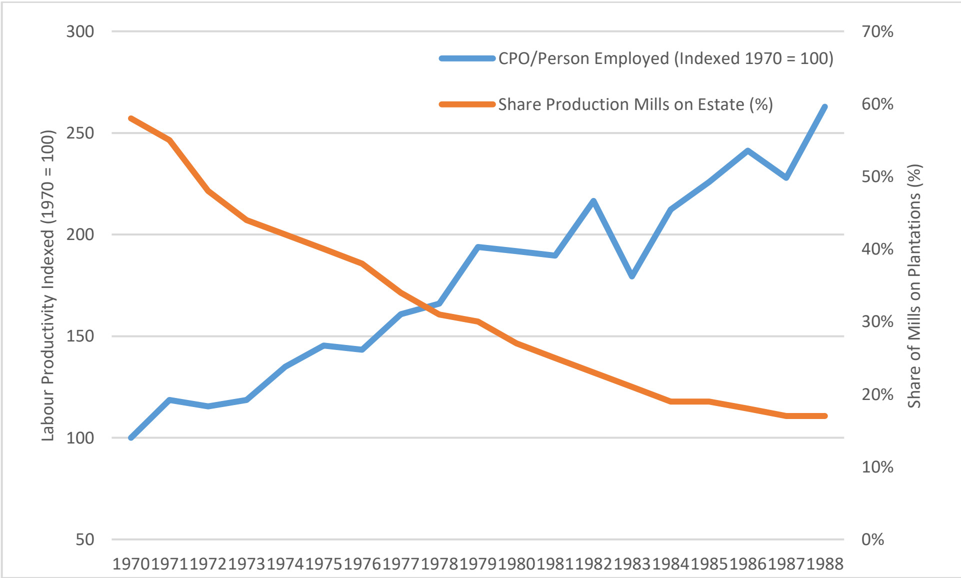

Figure 7: Labour Productivity Mills on Plantations and Production Share of Mills on Plantations 1970-1988

Note: For sources and a more detailed explanation of the estimation, see appendix 2

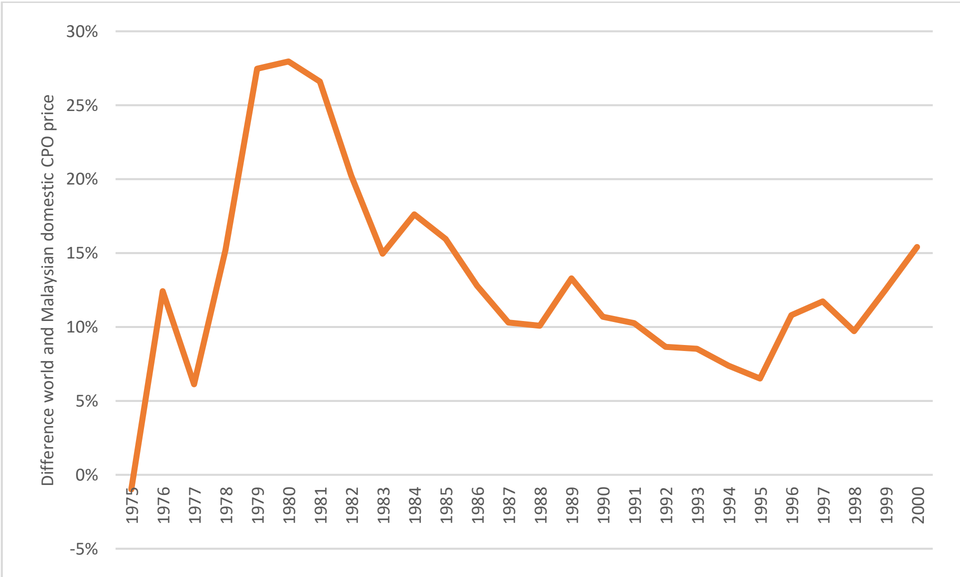

Figure 8: Percentage difference world market price and domestic Malaysian price 1975-2000

Source: Own calculations based on MPOB (2015); World market price is the prices in dollar per metric tonne registered on the North West Europe Market

Note: A positive figure means that the world market price was higher than in Malaysia

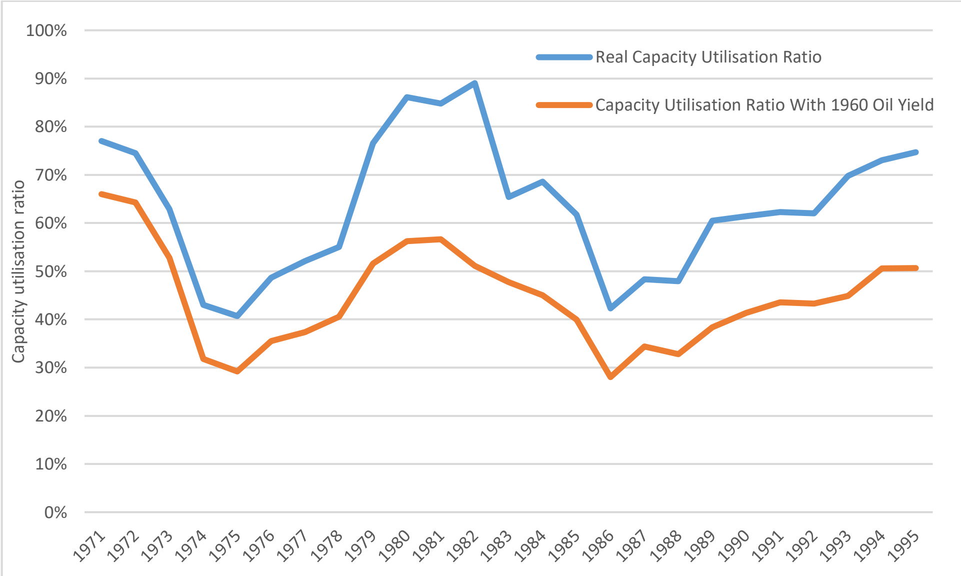

Figure 9: Capacity Utilisation Ratio Palm Oil Refineries 1971-1995

Source: Own calculations based on Gopal (2001)

Calculations used the actual share of crude palm oil processed when estimating for the 1960 oil yield

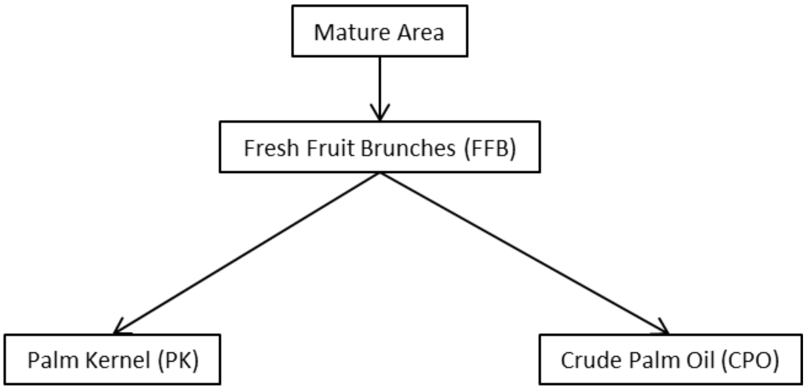

Figure Appendix 1.1: Illustration of the relationship between palm kernel and crude palm oil

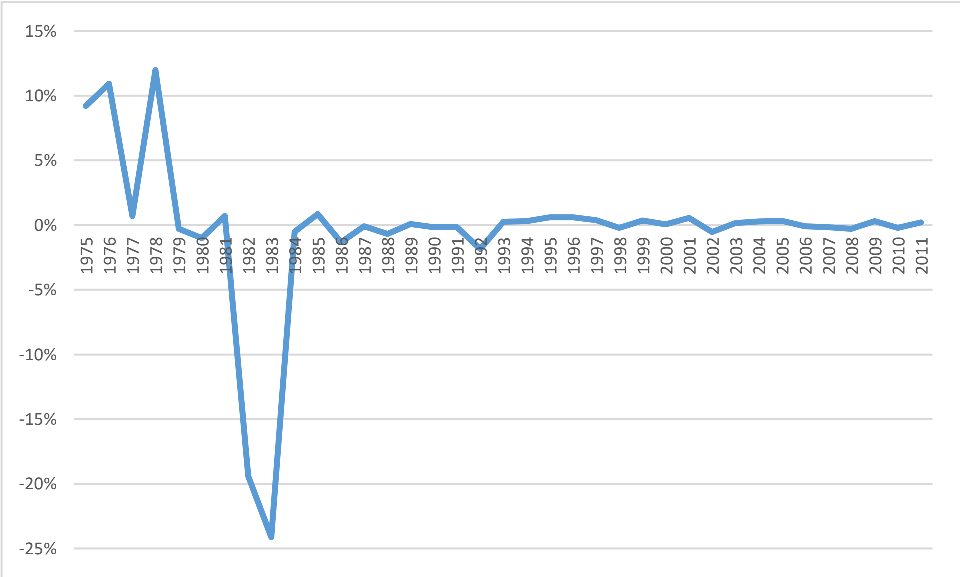

Figure appendix 1.2: Percentage difference in estimated mature area using equations A1.3 and A1.4

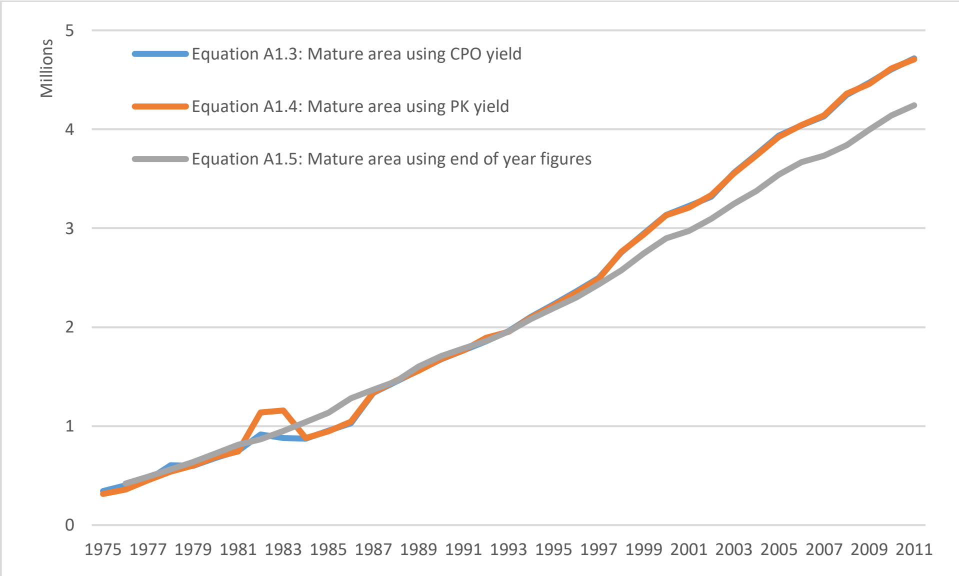

Figure appendix 1.3: Estimated yearly mature area

Source: For equations A1.3 and A1.4 see table appendix 1.1; for equation A1.5 data was gathered from MPOB (2012) table 1.2

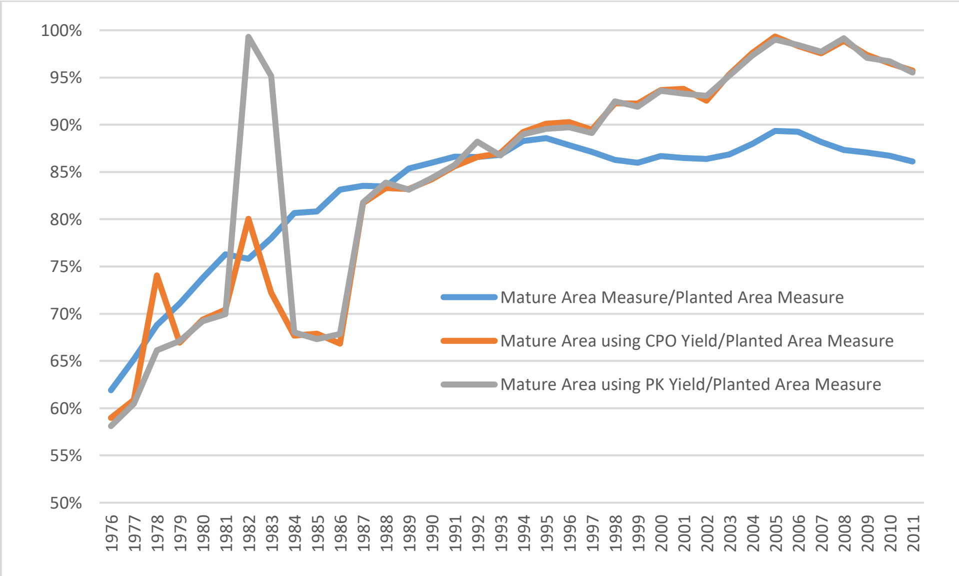

Figure Appendix 1.4: Mature Area as a % Share of Planted Area

Source: Mature area using CPO and PK Yield from table appendix 1.1, end of year figures for mature and planted area are gathered from MPOB (2011) table 1.2. The planted area measure is calculated the same way as the mature area measure by taking two end of year figures divided by two

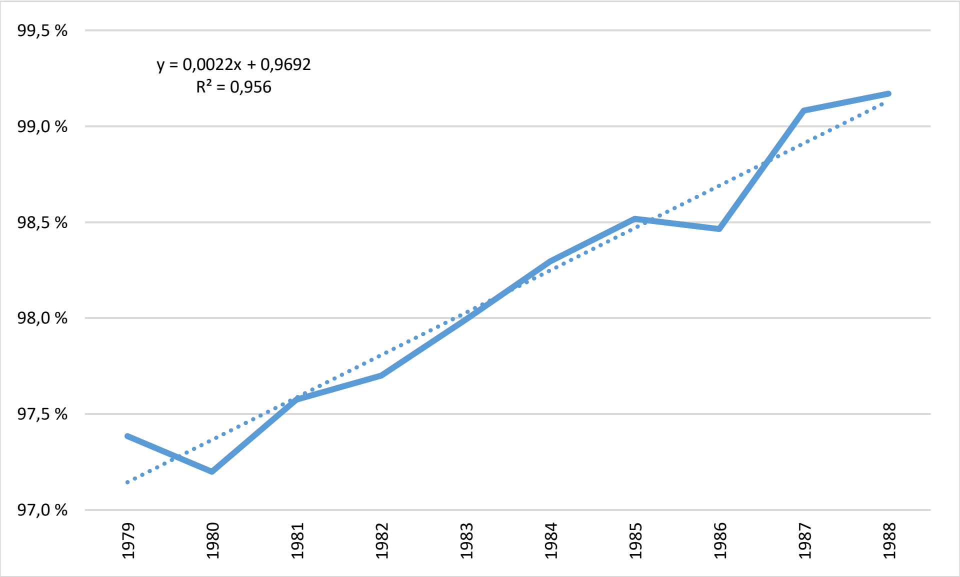

Figure Appendix 2.1: Number of Estate Workers as Share of Contract Workers 1979-1988

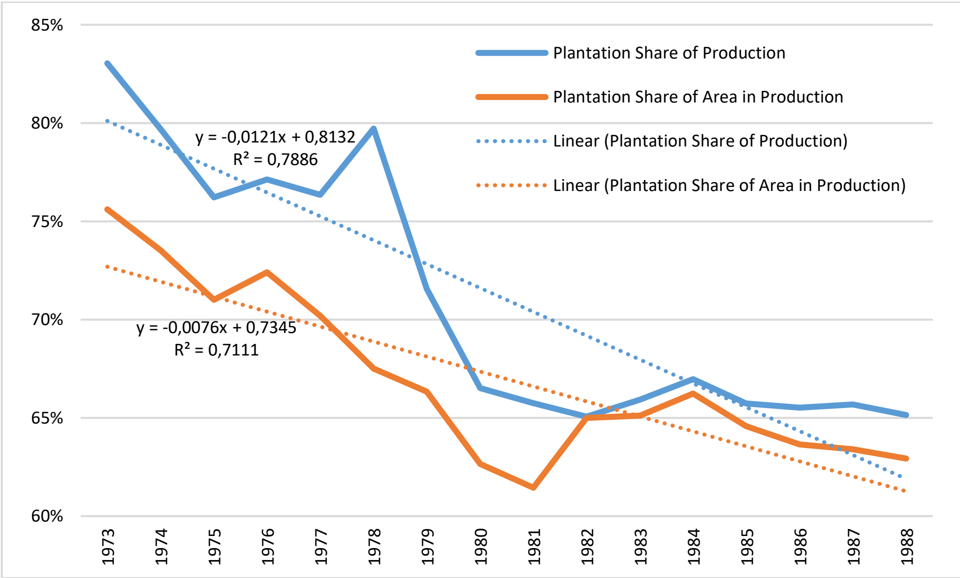

Figure appendix 2.2: Plantation share of production and area in production in peninsular Malaysia
Source: DoS (1973-1981) Table 32; DoS (1982-1983) Table 30; DoS (1984-1988) Table 6.2