UNIVERSITI PUTRA MALAYSIA

TECHNICAL EFFICIENCY ASSOCIATED WITH PRODUCTION INPUTS ACCORDING TO CROP AGE AMONG OIL PALM SMALLHOLDERS IN JOHOR, MALAYSIA

BULAMA ABISO TIJANI

FP 2017 4

TECHNICAL EFFICIENCY ASSOCIATED WITH PRODUCTION INPUTS ACCORDING TO CROP AGE AMONG OIL PALM SMALLHOLDERS IN JOHOR, MALAYSIA

By

BULAMA ABISO TIJANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

January 2017

DEDICATION

This research work is dedicated to the following important personalities for their love, care and support throughout my studies and indeed my entire life: my late grant father, Kaka Adam Mowozowo; my late father, Hon Tijjani Mohammed Adam; my late mother, Ya Khadija Mohammed; my late aunty, Bawa Aisa, my late grant mother, Kaka Hajja Bintu; and my lovely grant mother Ya Falmata Mataye.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

TECHNICAL EFFICIENCY ASSOCIATED WITH PRODUCTION INPUTS ACCORDING TO CROP AGE AMONG OIL PALM SMALLHOLDERS IN JOHOR, MALAYSIA

By

BULAMA ABISO TIJANI

January 2017

Chairman : Ismail Abd Latif, PhD
Faculty : Agriculture

The study measured technical efficiency associated with production inputs according to crop age among oil palm smallholders in Johor, Malaysia. Primary data were collected through multi-stage sampling procedure from a sample size of 450 independent oil palm smallholders randomly selected non-proportionately under young, prime and old crop age categories in ten (10) production units of Johor, Malaysia. Descriptive Statistics, DEA, DEA-bootstrap, FDH, Order-m, Order-alpha, SFA and PFF using COLS were employed to estimate and compare technical, allocative and economic efficiencies. Analysis of variance (one way ANOVA) was used to test for significance difference in mean TE, AE and EE efficiency according to crop age among smallholders while Tobit and OLS models were used to analyze the determinants of inefficiency. The mean technical efficiency (TE) estimates based on the variable returns to scale (VRS) for smallholders under young, prime and old crop age categories were 0.9601, 0.9412 and 0.9757 respectively while based on constant returns to scale (CRS) were 0.8616, 0.7092 and 0.9055 respectively. The mean SE estimates were 0.8986, 0.7466 and 0.9282 for the smallholders under young, prime and old crop age categories respectively. The mean allocative efficiency (AE) for the smallholders under young, prime and old crop age categories were 0.6248, 0.5905 and 0.6260 respectively while mean economic efficiency (EE) were 0.6146, 0.5286 and 0.5981 respectively. The finding also shows that there was significant difference in the mean TE and EE of the smallholders under young, prime and old crop age categories at 1% but no significant difference exists in the mean AE among the smallholders. The study also shows that age of farmer, education, household size, experience, off-farm income, oil palm income, government intervention, access to credit, age of crop squared, fertilizer, land clearing, extension contact, membership of smallholders association, replication of pesticides application and pest & weed control method have negative relationship with technical, allocative and economic inefficiency. The study identified unavailability of labour, low price for produce, high cost of farm inputs, low yield and high cost of labour as the major oil palm production problems in the

study area.There is need to re-strategies the extension program for effective monitoring and supervision of the smallholders' in order to ensure that they comply with recommended inputs use in order to enhance their efficiency levels. The study also recommend policies that would improve the quality of adult education extension program to educate the oil palm smallholders who owned young and prime crop age categories on how to use the various combinations of farm resources that can minimize cost of production appropriately.The oil palm smallholders should improve on their cooperative activities to enjoy economies of scale since they experience high cost of production which affects their profit.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KECEKAPAN TEKNIKAL BERKAITAN DENGAN INPUT PENGELUARAN BERGANTUNG PADA USIA TANAMAN DALAM KALANGAN PEKEBUN KECIL KELAPA SAWIT DI JOHOR, MALAYSIA

Oleh

BULAMA ABISO TIJANI

Januari 2017

Pengerusi : Ismail Abd Latif, PhD
Fakulti : Pertanian

Kajian ini mengukur kecekapan teknikal berkaitan dengan input pengeluaran bergantung pada usia tanaman dalam kalangan pekebun kecil kelapa sawit di Johor, Malaysia. Data utama telah dikumpul menggunakan prosedur persampelan multitahap dengan saiz sampel 450 pekebun kecil kelapa sawit persendirian yang dipilih secara rawak tanpa pembahagian kepada kategori tanaman muda, matang dan tua dalam sepuluh (10) unit pengeluaran di Johor, Malaysia. Statistik deskriptif, DEA, DEA-butstrap, FDH, Order-m, Order-alfa, SFA dan PFF menggunakan COLS telah dipakai untuk menganggar dan membandingkan kecekapan teknikal, alokatif, dan ekonomik. Analisis varians (ANOVA sehala) telah digunakan untuk menguji perbezaan signifikan dalam min kecekapan TE, AE, dan EE dalam kalangan pekebun kecil bergantung pada usia tanaman, manakala model Tobit dan OLS telah digunakan untuk menganalisis determinan ketidakcekapan. Min kecekapan teknikal (TE) dianggar berdasarkan pulangan variabel pada skala (VRS) bagi pekebun kecil di bawah kategori usia tanaman muda, matang, dan tua ialah masing-masing 0.9601, 0.9412 dan 0.9757, manakala mengikut pulangan variabel pada skala (CRS) ialah masing-masing 0.8616, 0.7092 dan 0.9055. Min SE dianggarkan ialah masing-masing 0.8986, 0.7466 dan 0.9282 bagi pekebun kecil di bawah kategori muda, matang, dan tua. Min kecekapan alokatif (AE) bagi pekebun kecil di bawah kategori usia tanaman muda, matang, dan tua ialah masing-masing 0.6248, 0.5905 dan 0.6260, manakala min kecekapan ekonomik (EE) ialah masing-masing 0.6146, 0.5286 dan 0.5981. Dapatan juga menunjukkan bahawa terdapat perbezaan yang signifikan dalam min TE dan EE bagi pekebun kecil di bawah kategori muda, matang, dan tua pada 1% tetapi tidak terdapat perbezaan yang signifikan dalam min AE antara pekebun kecil tersebut. Kajian juga menunjukkan bahawa umur petani, pendidikan, saiz isi rumah, pengalaman, pendapatan luar kebun, pendapatan kelapa sawit, intervensi kerajaan, akses pada kredit, usia tanaman squared, baja, pembersihan tanah, kontak pengembangan, keahlian persatuan pekebun kecil, replikasi aplikasi racun perosak, dan kaedah kawalan serangga & rumpai mempunyai hubungan yang negatif dengan ketidakcekapan

teknikal, alokatif, dan ekonomik.Kajian telah mengenal pasti faktor ketidakdapatan tenaga buruh, harga rendah bagi hasil, kos tinggi bagi input ladang, hasil rendah, dan kos buruh tinggi sebagai masalah utama pengeluaran minyak kelapa sawit di tempat yang dikaji.Terdapat keperluan untuk menstrategikan semula program pengembangan bagi pengawasan dan penyeliaan yang efektif bagi pekebun kecil bagi memastikan mereka mematuhi penggunaan input yang di syorkan bagi meningkatkan tahap kecekapan mereka.Kajian ini juga mengesyorkan polisi yang dapat mempertingkatkan kualiti program pengembangan pendidikan dewasa bagi mendidik pekebun kecil kelapa sawit yang memiliki kategori usia tanaman muda dan matang tentang bagaimana untuk menggunakan pelbagai kombinasi sumber ladang yang dapat meminimumkan kos pengeluaran dengan sewajarnya.Pekebun kecil minyak kelapa sawit harus menambah baik aktiviti koperasi mereka supaya dapat menikmati skala ekonomi kerana mereka menghadapi kos pengeluaran yang tinggi yang memberikan kesan pada keuntungan mereka.

ACKNOWLEDGEMENTS

Thanks and praises be to ALMIGHTY ALLAH the omniscience, beneficent and the forgiving who offered the ability and strength to overcome all challenges before and during the period of my study to attain this level of education, and indeed accomplish this research work. I would like to first and foremost express my gratitude and appreciation to my supervisory committee chairman and members, Dr. Ismail Abd Latif, Prof. Mad Nasir Shamsudin and Dr. Nitty Hirawaty Kamarulzaman for their constructive criticisms, valuable suggestions, fatherly advices, intellectual and well-articulated guidance throughout the journey of this research study. I was not only supervised but enthused the desire for academic life. My appreciation also goes to my lecturers in the Department, Prof. Zainal Abdin Mohammed, Prof. Muhammed Mansor Ismail, Dr. Amin Mahir Abdullah, Dr. Nolila, Dr. Juwaida and Dr. Alias Radam of Faculty of Economics for their various kind of supports. My appreciation goes to Eng. Dr. Babagana Umara who persuaded and supported me to come to Malaysia for my PhD programme. I would also like to acknowledge the support of my employer and sponsor, Ramat Polytechnic Maiduguri Nigeria through the Tertiary Education Trust Fund (TETFUND).

I would like to acknowledge the prayers and supports of my wife Yagana and my daughters, Khadija and Fatimah Abiso; and my father Alhaji Abdulkadir Jidda; my elder brother Alhaji Bulama Abiso and his wife Hajiya Hauwa; my uncles Alh. Abba Ibrahim, Mal. Ali Gana, Abba Masta, Alh. Bukar Adam and Mal. Hassan. I appreciate the support of my siblings Mamman, Ba Jumba, Ba Abba, Ba Lawan, Abubakar, Shettima, Abdulkadir, Hamsatu, Yagana Falmata and Yagana Mayram. Equally worthy of mention are my friends and colleagues both at home and here in Malaysia during the period of our study. My special appreciation goes to Dr. Bashir Gabdo, Dr. Abdullahi Iliyasu, Dr. Shettima Zimboh, Bale Bura, Mohammed Tijjani (Doctor), Bulama (Abless), Baba Jimeta, Hassan Tijani, Dr. Muhd Goni, Dr. Sulumbe, Aliyu Abdullahi Barde, Abdullahi Alkali, Bale Bukar and others too numerous mention. My class mates and colleagues; Dr. Mustapha Mbele, Dr. Ibrahim Mustapha, Dr. Konto, Dr. Mustapha Yaganabe, Dr. Aliyu Maiha, Dr. Abdullahi Illyasu, Dr. Auwal Ahmed, Umar Muktar, Dr. Henry, Dr. Aliyu Abdulrahman, Dr. Bashir, Dr. Kaka Yahaya, Dr. Kabiru Maji, Dr. Umar Bala, Dr. Suleiman Chindo, Salisu Waziri, Kamal. Finally, I would like to acknowledge the financial and logistic supports received from Universiti Putra Malaysia during the study period. I would also like to extend my appreciation to Staff of Malaysian Oil Palm Board (MPOB) and the enumerators for aiding data collection for this study.

I certify that a Thesis Examination Committee has met on 25 January 2017 to conduct the final examination of Bulama Abiso Tijani on his thesis entitled "Technical Efficiency Associated with Production Inputs According to Crop Age among Oil Palm Smallholders in Johor, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Zainal Abidin bin Mohamed, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Mohd Mansor bin Ismail, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Amin Mahir bin Abdullah, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Nuhfil Hanani, PhD
Professor Ir.
Universitas Brawijaya
Indonesia
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 28 April 2017

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Ismail Abd Latif, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Mad Nasir Shamsudin, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Nitty Hirawaty Kamarulzaman, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: ________________________________ Date: ________________

Name and Matric No: Bulama Abiso Tijani, GS36559

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: ____________________
Name of Chairman of Supervisory Committee: Dr. Ismail Abd Latif

Signature: ____________________
Name of Member of Supervisory Committee: Professor Dr. Mad Nasir Shamsudin

Signature: ____________________
Name of Member of Supervisory Committee: Associate Professor Dr. Nitty Hirawaty Kamarulzaman

TABLE OF CONTENTS

				Page
ABSTRACT				i
ABSTRAK				iii
ACKNOWLEDGEMENTS				v
APPROVAL				vi
DECLARATION				viii
LIST OF TABLES				xiii
LIST OF FIGURES				xvi
LIST OF ABBREVIATIONS				xviii
CHAPTER				
1	**INTRODUCTION**			1
	1.1	Background of the Study		1
	1.2	Statement of the Problem		15
	1.3	Objectives of the Study		18
	1.4	Significance of the Study		19
	1.5	Statement of Research Hypothesis		20
	1.6	Scope of the Study		20
	1.7	Organization of the Study		20
2	**LITERATURE REVIEW**			22
	2.1	Empirical Studies on Technical, Allocative and Economics Efficiency		22
	2.2	Methodological Issues		45
	2.3	Issues and Challenges Faced by Smallholders		50
3	**METHODOLGY**			53
	3.1	Conceptual Framework for Oil Palm Production Efficiency According to Crop Age		53
	3.2	Farrell's Concept of Technical, Allocative and Economic Efficiency		54
		3.2.1	Input-Oriented Measures of Efficiency	54
		3.2.2	Output-Oriented Efficiency Measures	56
	3.3	Theoretical Framework		58
		3.3.1	The Production Theory	58
		3.3.2	Efficiency Measurement Approaches	61
		3.3.3	Data Envelopment Analysis	62
		3.3.4	Stochastic Frontier Production Function Analysis	65
		3.3.5	Parametric Full Frontier	67
		3.3.6	Robust Efficiency Estimators	69
		3.3.7	DEA Bootstrap Estimator	73
	3.4	Tobit Regression Model		78
	3.5	Ordinary Least Square (OLS) Regression Model		79
	3.6	Study Area		80
	3.7	Sources and Method of Data Collection		83
	3.8	Validation of Instrument for Data Collection		83

	3.9	Nature of Data used for the Study	84
	3.10	Sampling Techniques	85
		3.10.1 Determination Sample Size for the Study	87
	3.11	Analytical Techniques	87
		3.11.1 Descriptive Statistics	88
		3.11.2 Empirical DEA Model Specification	88
		3.11.3 Empirical Model for Stochastic Frontier Production Estimation	91
		3.11.4 Empirical Model for Estimation of Parametric Full Frontier using (COLS)	93
		3.11.5 Tobit and OLS Regression Analysis	94
	3.12	A Priori Expectation of the Signs of Production Inputs and Determinants of Inefficiency variables	95
4	**RESULTS AND DISCUSSION**		99
	4.1	Socio-economic Characteristics of the Oil Palm Smallholders According to the Crop Age	99
	4.2	Detection of Outliers in Smallholder Oil Palm Production Data and Diagnostic Statistics According to Crop Age	103
		4.2.1 Diagnostic Statistics for the Variables used in Smallholder Oil Palm Production According to Crop Age	105
	4.3	Summary Descriptive Statistics of the Data used for the Analyses of Efficiencies Associated with Production Inputs	106
	4.4	Estimates of Technical, Allocative and Economic Efficiencies based on DEA Estimator	112
	4.5	Technical Efficiency TE FDH and TE Order-alpha Models for Oil Palm Smallholders according to Crop Age	114
	4.6	Comparison the Performances of the Data Envelopment Analysis (DEA), Stochastic Frontier (SFA) and Parametric Full Frontier (PFF) in Measuring the Technical Efficiency of Oil Palm Smallholders	117
	4.7	Estimates of Inputs and Output Slacks of Oil Palm Smallholders According to Crop Age based on DEA Estimator	120
	4.8	Standardized Leveled Bootstrap for Optimization of Technical Efficiency of Oil Palm Smallholders According to Crop Age	124
	4.9	Hypotheses Testing for Mean Difference in Technical, Allocative and Economic Efficiencies	132
	4.10	Maximum Likelihood Estimates of Cobb-Douglas Stochastic Frontier Production of Oil Palm Smallholders According to Crop Age	135
	4.11	Determinants of Technical, Allocative and Economic Inefficiency	145
	4.12	Comparison of Estimated Determinants of Technical, Allocative and Economic inefficiency based on Different Estimators According to Crop Age	161
	4.13	Problems Encountered by Oil Palm Smallholders according to Crop Age	172

5	**SUMMARY AND CONCLUSION**		173
	5.1	Summary	173
	5.2	Implications of the study for policy	181
	5.3	Recommendations for policy measures	182
	5.4	Limitations of the study and suggestions for future study	182
	5.5	Conclusion	182

REFERENCES	184
APPENDICES	204
BIODATA OF STUDENT	234
LIST OF PUBLICATIONS	235

LIST OF TABLES

Table		Page
1.1	Representation of the Research Hypothesis	20
3.1	Distribution of Independent Oil Palm Smallholders Interviewed	87
3.2	A Priori Expectation of the Sigs of Production Inputs and Determinants of Inefficiency variables	97
4.1	Socio-economic Characteristics of Oil Palm Smallholders According to Crop Age	101
4.2	Summary Descriptive Statistics of Output/Inputs and Inputs Prices of Oil Palm Smallholders according to Crop Age	109
4.3	Summary Descriptive Statistics of the Determinants of Inefficiency among Oil Palm Smallholders according to Crop Age	110
4.4	Summary of Descriptive Statistics of Dummy Variables used for Determinants of Inefficiency Analysis	111
4.5	Estimated Result of Technical Efficiency (TE) of Oil Palm Smallholders According to Crop Age	112
4.6	Estimated Result of Non-Increasing Return (NIRTS) to Scale Efficiency (SE) and Scale Efficiency of Oil Palm Smallholders According to Crop Age	113
4.7	Estimated Results of Technical Efficiency (TE) FDH and Order-alpha Models for Oil Palm Smallholders according to Crop Age	115
4.8	Estimated Results of Technical Efficiency TE Order-m Model for Oil Palm Smallholders according to Crop Age	116
4.9	Estimated Technical Efficiency (TE) of Oil Palm Smallholders according to Crop Age based on DEA, SFA & PFF Estimators	117
4.10	Estimated Allocative Efficiency (AE) of Oil Palm Smallholders according to Crop Age based on DEA & SFA Estimators	118
4.11	Estimated Economic Efficiency (EE) of Oil Palm Smallholders according to Crop Age based on DEA & SFA Estimators	119
4.12	Estimates of Input and Output Slacks of Oil Palm Smallholders under Young Crop Age Category based on DEA Estimator	121

4.13	Estimates of Inputs and Output Slacks of Oil Palm Smallholders under Prime Crop Age Category based on DEA Estimator	122
4.14	Estimates of Inputs and Output Slacks of Oil Palm Smallholders under Old Crop Age Category based on DEA Estimator	124
4.15	Estimated Result of Non-Bias Corrected Technical Efficiency of Oil Palm Smallholders According to Crop Age based on DEA-bootstrap Estimator under VRS assumption	125
4.16	Estimated Result of Bias-corrected Technical Efficiency of Oil Palm Smallholders According to Crop Age based on DEA-Bootstrap Estimator under VRS assumption	126
4.17	Estimated Result of Bias-corrected NIRTS Technical Efficiency and Scale Efficiency of Oil Palm Smallholders According to Crop Age based on DEA-bootstrap Estimator under NIRTS assumption	127
4.18	Result of Bias Estimates Technical Efficiency of Oil Palm Smallholders According to Crop Age based on DEA-bootstrap Estimator under VRS assumption	128
4.19	Confidence Interval for Bias-corrected Technical Efficiency of Oil Palm Smallholders According to Crop Age	130
4.20	Matrix of Mean Efficiency Estimates According to Crop Age Based on Different Estimators	131
4.21	Hypotheses Testing for Mean Difference in Technical, Allocative and Economic Efficiencies among Oil Palm Smallholders According to Crop Age	133
4.22	Hypotheses Testing for Multiple Comparison Difference of Mean Technical, Allocative and Economic of the Oil Palm Smallholders According to Crop Age	134
4.23	Maximum Likelihood Estimates of Cobb-Douglas Stochastic Frontier Production of Oil Palm Smallholders According to Crop Age	136
4.24	Estimated Elasticities of Inputs and Return to Scale (RTS) for Smallholders Oil Palm Production According to Crop Age	136
4.25	Maximum Likelihood Estimates of the Determinants of Technical Inefficiency among Oil Palm Smallholders According to Crop Age	138
4.26	Generalized Likelihood Ratio Test of Cobb-Douglas Stochastic Production Function for Oil Palm Smallholders According Crop Age Category	144

4.27	Tobit Regression Model Estimates of the Determinants of Technical Inefficiency among Oil Palm Smallholders According to Crop Age	146
4.28	Tobit Regression Model Estimates of the Determinants of Allocative Inefficiency among Oil Palm Smallholders According to Crop Age	150
4.29	Tobit Regression Model Estimates of the Determinants of Economic Inefficiency among Oil Palm Smallholders According to Crop Age	154
4.30	Ordinary Least Square (OLS) Estimates of Determinants of Technical Inefficiency among Oil Palm Smallholders According to Crop Age (using the Bias-corrected TEVRS)	157
4.31	Ordinary Least Square (OLS) Estimates of Determinants of Allocative Inefficiency among Oil Palm Smallholders According to Crop Age	159
4.32	Ordinary Least Square (OLS) Estimates of Determinants of Economic Inefficiency among Oil Palm Smallholders According to Crop Age	161
4.33	Matrix of the Results of Determinants of Technical Inefficiency According to Crop Age Based on Different Estimators	169
4.34	Matrix of the Results of Determinants of Allocative Inefficiency According to Crop Age Based on Different Estimators	170
4.35	Matrix of the Results of Determinants of Economic Inefficiency According to Crop Age Based on Different Estimators	171
4.36	Problems Encountered by Oil Palm Smallholders according to Crop Age	172

LIST OF FIGURES

Figure		Page
1.1	The topmost 20 Palm Oil Producing Countries of the World	2
1.2	Malaysian Palm Oil Export (Millions Metric Tons)	3
1.3	Malaysian Palm Oil Export Value (Millions RM)	4
1.4	Malaysian Crude Palm Oil Production (Millions Metric Tons)	5
1.5	Malaysian's Regional Crude Palm Oil Production (Millions Metric Tons)	5
1.6	Malaysian Oil Palm Planted Area According States (ha)	6
1.7	Percentage of Malaysian Oil Palm Planted Area by States (ha)	6
1.8	Malaysian Oil Palm Planted Area (Matured and Immatured) by States (ha)	7
1.9	Percent Distribution of Malaysian Oil Palm Planted Area (Matured and Immatured) by States (ha)	8
1.10	Category of Malaysian Oil Palm Planted Area (ha)	8
1.11	Malaysian Total Oil Palm Planted Area according to Region (ha)	9
1.12	Independent Oil Palm Smallholders Planted Area in Malaysia According to States (ha)	10
1.13	Percent Distribution of Planted Area by Independent Oil Palm Smallholders in Malaysia According to States (ha)	10
1.14	Oil Palm Planted Area by Independent Smallholders in Johor According to District (ha)	11
1.15	Population of Independent Oil Palm Smallholders in Malaysia According to States	12
1.16	Percent Distribution of Independent Oil Palm Smallholders in Malaysia According to States	12
1.17	Population of Independent Oil Palm Smallholders in Johor According to District	13
1.18	Percent Distribution of Independent Oil Palm Smallholders in Johor According to District	13

1.19	Malaysia's Oil Palm Age and Yield Profile	15
1.20	Yield Potential of Palm Oil (MT t/ha)	16
1.21	Oil Palm Yield FFB t/ha according to Age of Crop before & After Technology Advancement in Malaysia	18
3.1	Conceptual Framework for Oil Palm Production Efficiency According to Crop Age	53
3.2	Input-Output Measure for Technical, Allocative and Economic Efficiencies	55
3.3	Output-Oriented Measure for Technical, Allocative and Economic Efficiencies	57
3.4	Graphical Representation of Technology Set	59
3.5	Graphical Representation of Input Set	59
3.6	Graphical Representation of Output	60
3.7	The Production Procedure and Production Function	60
3.8	Map of Malaysia Showing the Location of Johor State	81
3.9	Map of Johor State showing the districts	83
4.1	Detection of Outliers in Smallholder Oil Palm under Young Crop Age Category	104
4.2	Detection of Outliers in Smallholder Oil Palm under Prime Crop Age Category	104
4.3	Detection of Outliers in Smallholder Oil Palm under Old Crop Age Category	105

LIST OF ABBREVIATIONS

AE	Allocative Efficiency
CE	Cost Efficiency
COLS	Corrected Ordinary Least Square
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DGP	Data Generating Process
DMU	Decision Making Unit
DRS	Decreasing Return to Scale
EE	Economic Efficiency
ETP	Economic Transformation Programme
FDH	Free Disposal Hull
FELCRA	Federal Land Consolidated and Rehabilitated Authority
FELDA	Federal Land Development Authority
FFB	Fresh Fruits Brunches
GDP	Gross Domestic Product
IRTS	Increasing Return to Scale
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Council
MPOC	Malaysian Palm Oil Promotion Council
MT	Million Metric Tons
NIRTS	Non-increasing Return to Scale
OLS	Ordinary Least Square
OTE	Overall Technical Efficiency
PFF	Parametric Full Frontier

RISDA	Rubber Information Smallholder Development Authority
RM	Ringgit Malaysia
RTS	Return to Scale
SE	Scale Efficiency
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
TECRS	Technical Efficiency Variable Return to Scale
TEVRS	Technical Efficiency Variable Return to Scale
USDA	United States Department of Agriculture
VRS	Variable Return to Scale

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Agriculture is a significant sector to the Malaysia's economic growth, it create wealth and alleviate poverty principally amongst folks from the rural areas. The Malaysia's agricultural sector is sub-grouped into estate and smallholders' sub-sectors. The estate sub-sector is vastly commercialized and usually owned by public-listed corporate entities, private companies and even public land development agencies. The smallholders' sub-sector comprising independent and organized is less commercialized and thus, need to be effectively managed by the authorities and ensure that all farm inputs are judiciously; and efficiently utilized to obtain high output at minimum cost.

The private companies in Malaysia are mainly concerned in the production of industrial and export crops such as oil palm and rubber. These most important crops are produced mainly for exports as they contribute to the Malaysia's Gross Domestic Product (GDP). The record of Malaysia's agriculture can be traced back to periods of British Administration, many highly profitable perennial commercial crops such as palm oil and rubber among others were introduced and promoted. Ever since then, these crops became the main agricultural exports to global market in Malaysia. According to statistics, agricultural industry generates about 12 percent to the National Gross Domestic Product (GDP) and also lessen unemployment rate in Malaysia (Malaysian Business Online, 2011).

Malaysia remained the world's second key provider of palm oil after Indonesia. The two countries accounted for about 85% of the world's overall palm oil production. The world's demand for palm oil has increased by an average of 2.3 million tons yearly over the last decades (Oil World, 2014). About 62% of the palm oil required to satisfy this demand was provided by Indonesia, while 30% was supplied by Malaysia and other countries in the world supplied about 8%. This trend of palm oil supply is expected to sustain as overall palm oil demand is anticipated to ascend by additional 5 million tons annually. Malaysia and Indonesia alone are accountable for over 80 per cent of the overall world palm oil production. In 2015, Malaysia produced about 20,500,000 million MT of palm oil as the second producer while Indonesia produced 33,000,000 million MT and remain the largest world producer of palm oil according to United States Department of Agriculture (USDA) (2015). The topmost world leading palm oil producing countries alongside Indonesia and Malaysia includes Thailand, Colombia, Nigeria, Papua New Guinea, Ecuador, Ghana and Honduras among others (see figure 1. 1).

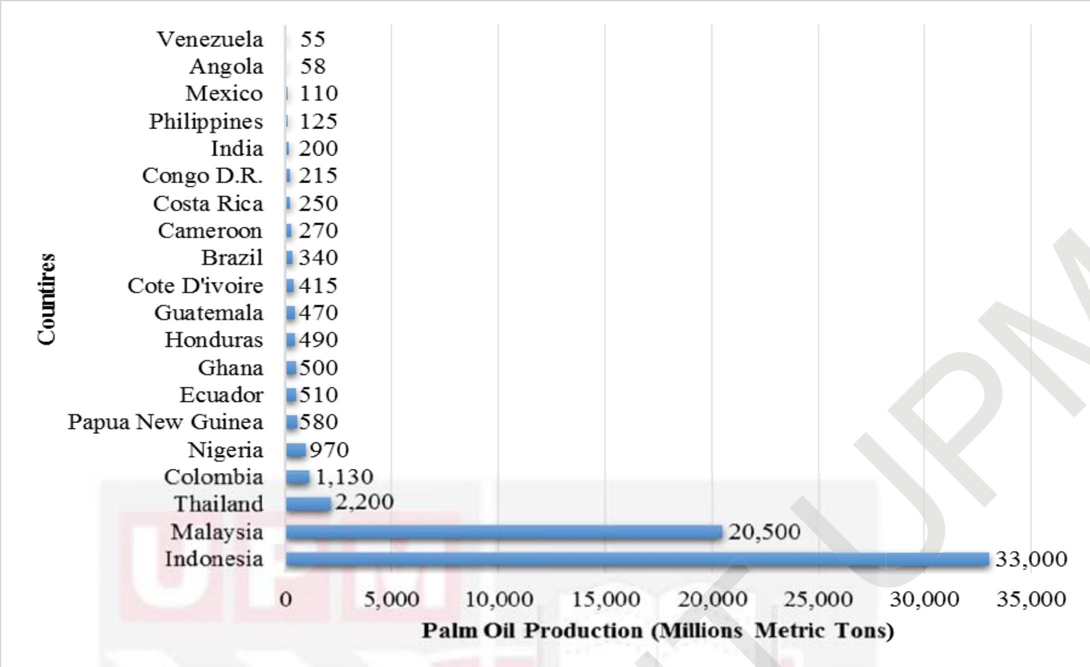

Figure 1.1 : The topmost 20 Palm Oil Producing Countries of the World
(Source: USDA (2015))

The Malaysia's oil palm industry plays a vital part in growth of the country's agriculture sector based on its contribution to the GDP, foreign exchange and also employment. The oil palm sub-sector is the largest contributor in the Malaysia's agricultural sector where it provided as much as 32.4% by the year 2008 (Fadhilah *et al.,* 2010). At some point in the 8th Malaysia Plan (2001-2005) agricultural sector grow at 3.2 percent per annum and by 10th Malaysian Plan (2011-2015), the growth rate was anticipated to fall to 3.0 percent per annum (10th Malaysia Plan 2010). In tandem to the observation of 10th Malaysia Plan (2010), the agricultural sector's contribution to the Malaysian GDP grew at a slower pace of 4.7% in 2011 and decreased to 4.1% in 2012, which gave a short fall of 0.6% (Malaysian Economic Report, 2011/2012). In 2015, the agricultural sector increased its contribution to the Malaysian GDP by 8.9% (Department of Statistics Malaysia, 2016), whereas the oil palm industry's contribution increased to 46.9 per cent and remained the main supplier to the GDP of Malaysian agricultural sector. This was followed by 17.7% contributed by other agriculture while fishing and livestock each (10.7%), rubber (7.2%) and forestry and logging (6.9%) in 2015 (Department of Statistics Malaysia, 2016).

Palm oil has been one of the major factor in Malaysia's economy, reducing poverty from 50 per cent in the 1960s, down to less than 5 per cent by 2015 (Aikanathan *et al.,* 2015). The oil palm industry being the larger contributor to the Malaysia's national economy play a vital role in eradicating poverty and directly providing job to over 610,000 persons, with more than 177,000 oil palm smallholders in the country (Economic Transformation Programme ETP, 2012). According to the Malaysian Palm Oil Council (MPOC) (2014), palm oil remained a principal export earner in Malaysia, among the primary commodities, and the volume of export for 2013, 2014 and 2015 were 25,702,707, 25,072,103 and 25,370,294 million MT respectively (see figure 1. 2). The export value for 2013, 2014 and 2015 were estimated at RM61, 363.35, RM63, 618.87 and RM60, 169.49 billion respectively, accounting for about 9 per cent of Malaysian export earnings (figure 1. 3). In 2014, the Malaysian palm oil industry's size of exports recorded a drop, though there was high returns due to mainly high price. ''The palm oil exports and derived products cut down to 25.1 million tons or by 2.5 percent from 25.7 million tons year-on-year. But earnings from palm oil increased by 3.7 percent to RM63.6 billion from RM61.4 billion in 2013 and RM60.2 billion in 2015'' (MPOB, 2014 and 2015). While the mean crude palm oil price went up by a small increase of 0.5 percent over the relative periods.

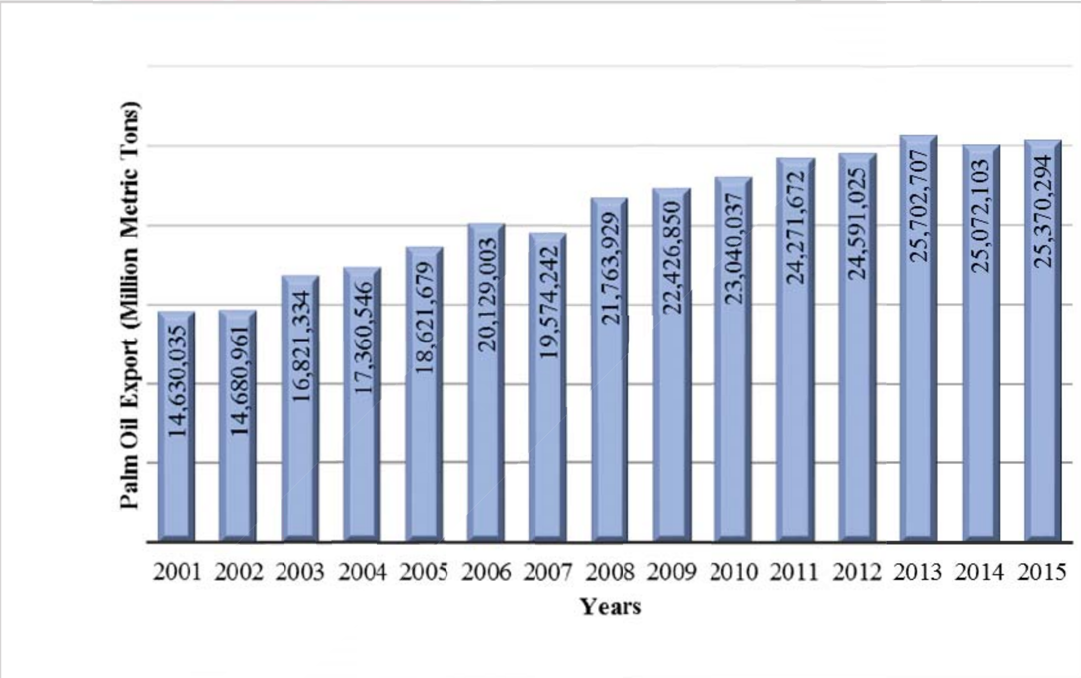

Figure 1.2 : Malaysian Palm Oil Export (Millions Metric Tons)
(Source: MPOB (2015))

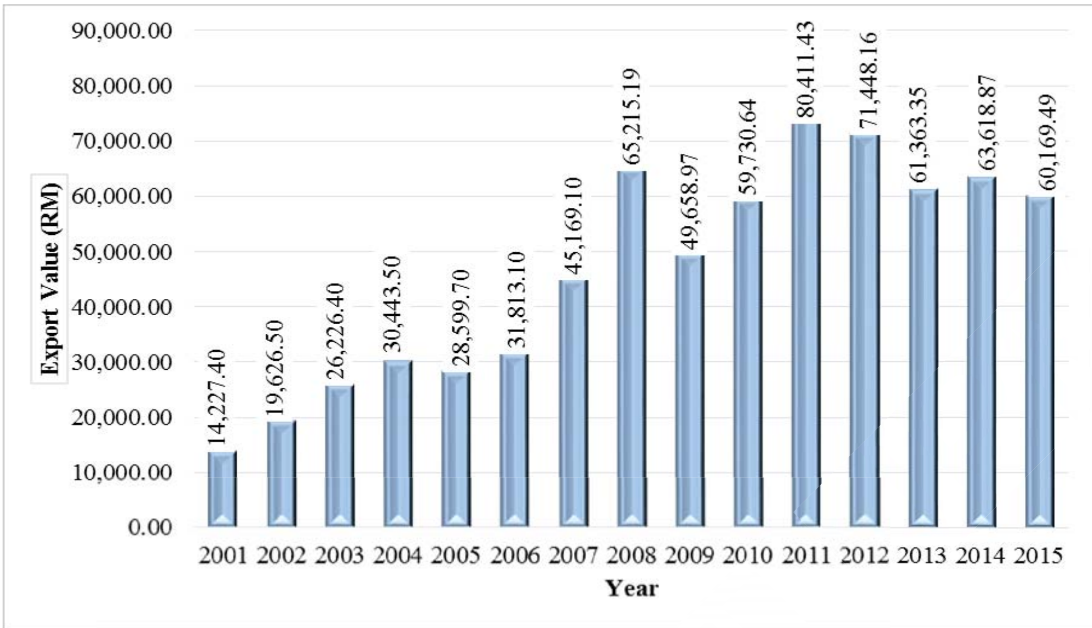

Figure 1.3 : Malaysian Palm Oil Export Value (Millions RM)
(Source: MPOB (2015))

In 2013, about 19,216.459 million metric tons (MT) of crude palm oil was produced in Malaysia while 19,667,016,000 and 19,961,581,000 million MT were for 2014 and 2015 respectively (MPOB, 2015) (see figure 1. 4). At the regional level in 2013, Peninsula Malaysia produced about 10,328,025,000 million MT crude palm oil, Sabah & Sarawak produced 8,888,434,000 million MT while crude palm oil production in 2014 was 10,172,108,000 and 9,494,908,000 million MT for Peninsula Malaysia, Sabah & Sarawak respectively (MPOB, 2015). Furthermore, the crude palm oil output during the 2015 production year for Peninsula Malaysia was 10,536,467,000 million MT while 9,425,114,000 was for Sabah & Sarawak (MPOB, 2015) (see figure 1. 5).

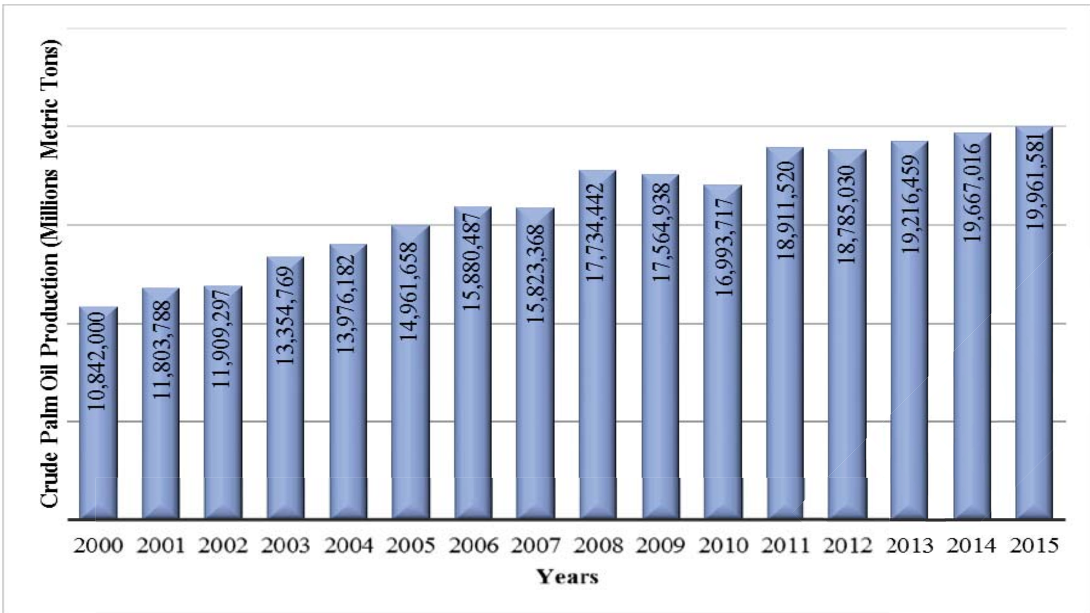

Figure 1.4 : Malaysian Crude Palm Oil Production (Millions Metric Tons) (Source: MPOB (2015))

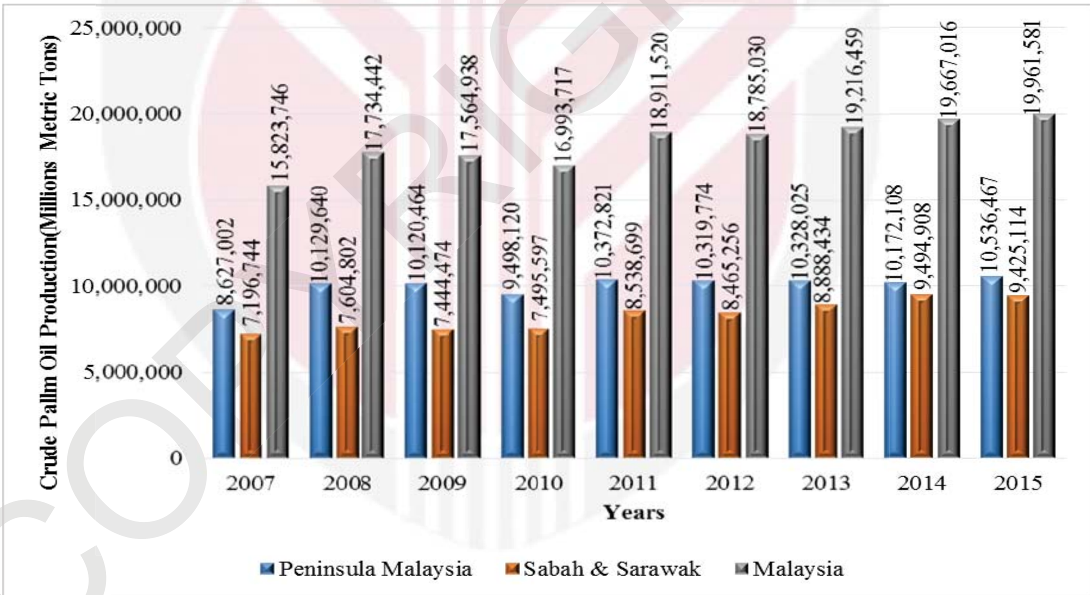

Figure 1.5 : Malaysian's Regional Crude Palm Oil Production (Millions Metric Tons) (Source: MPOB (2015))

Malaysia had around 5.23 million hectares of oil palm planted areas in 2013. At the States level, Sabah & Sarawak have the largest oil palm planted area with 1,511,510 (28%) and 1,263,391(23.5%) hectares respectively followed by Johor and Pahang with 733,467 (13.6%) and 719,613 (13.3%) hectares respectively in Peninsula Malaysia (MPOB, 2014) see figure 1. 6 and 1. 7.

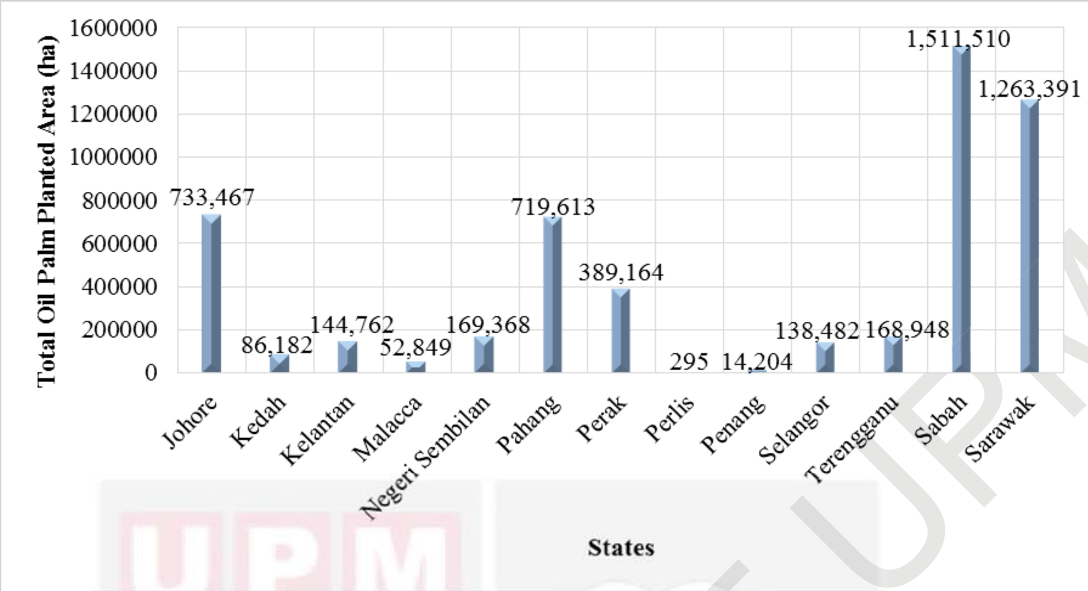

Figure 1.6 : Malaysian Oil Palm Planted Area According States (ha)
(Source: MPOB (2014))

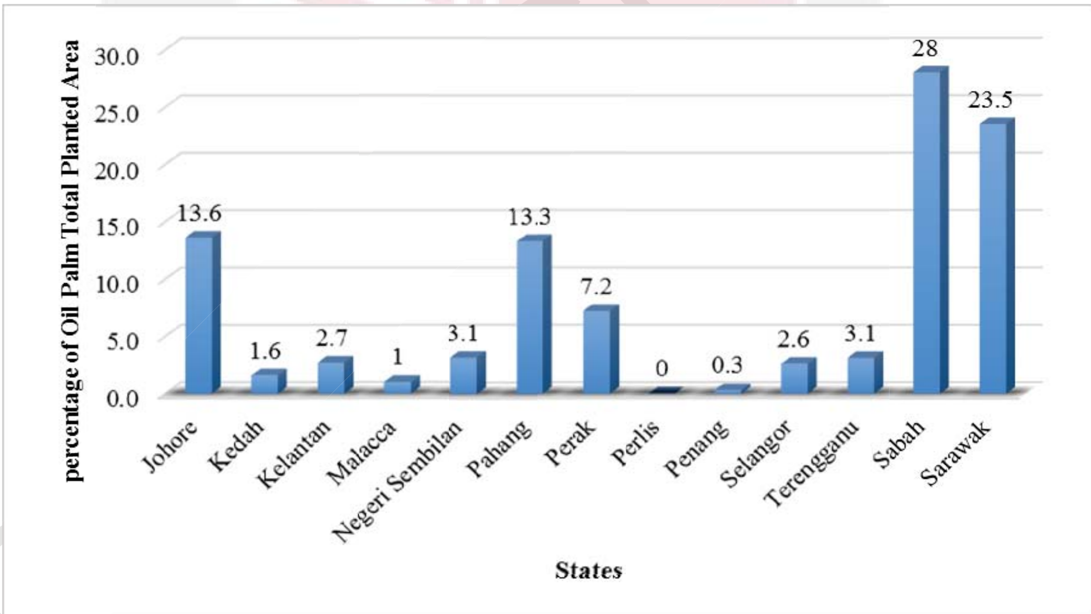

Figure 1.7 : Percentage of Malaysian Oil Palm Planted Area by States (ha)
(Source: MPOB (2014))

The matured and immatured oil palm planted area of Malaysia according to States shows highest matured 1,355,541 (89.7%) and immatured 155,969 (10.3%) hectares in Sabah and matured 1,058,208 (83.8%) and immatured 205,183 (16.2%) hectares in Sarawak. The highest 651,242 (88.8%) matured and 82,225 (11.2%) hectares of immatured oil palm planted area in Johor followed by matured 623,269 (86.6%) and immatured 96,344 (13.4%) hectares in Pahang of Peninsula Malaysia (MPOB, 2014), see figures 1. 8 and 1. 9. ‘’The oil palm industry was largely subjugated by big plantation companies generally possessed by private stakeholders and government linked companies that accounts for 61% of the overall oil palm planted area in terms of category of ownership'' (MPOB, 2015).''Though, a substantial portion of oil palm planted area was in the ownership of organized smallholders and independent smallholders still accounts for 23 percent and 16 percent of the overall area, respectively'' (MPOB, 2015), see figure 1. 10. Oil palm Smallholders constitutes about 39% of Malaysia's oil palm area and as much as 33 percent of the output and are being strongly supported by the government to boost their overall FFB yield. This is part of the task to achieve the 2020 target of raising annual FFB yields to 26.2t/ha as the national average across all categories of ownership, smallholdings and plantations included.

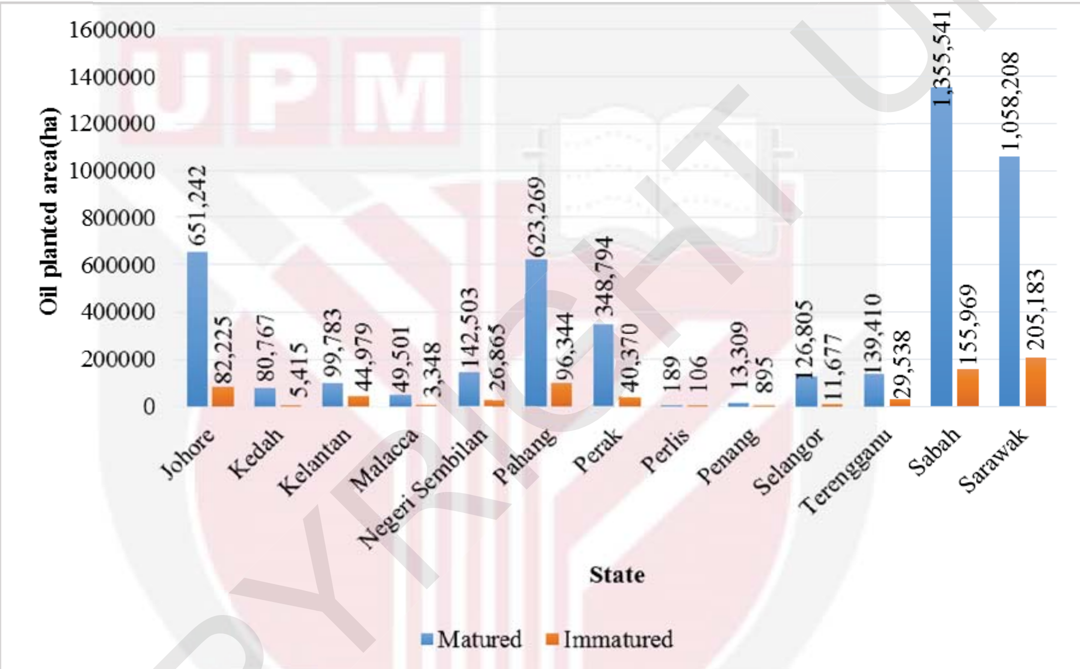

Figure 1.8 : Malaysian Oil Palm Planted Area (Matured and Immatured) by States (ha) (Source: MPOB (2014))

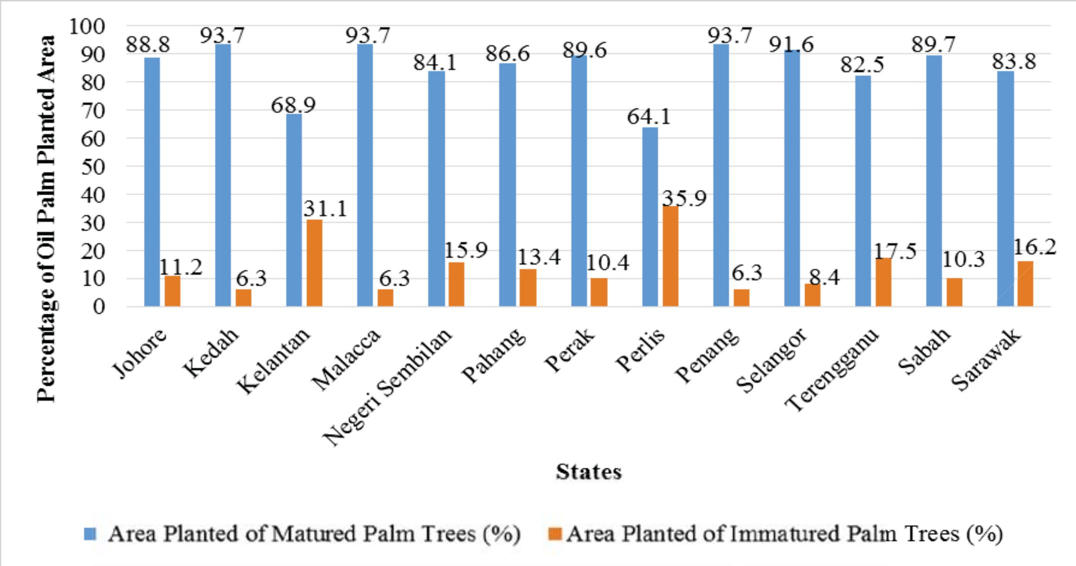

Figure 1.9 : Percent Distribution of Malaysian Oil Palm Planted Area (Matured and Immatured) by States (ha) (Source: MPOB (2014))

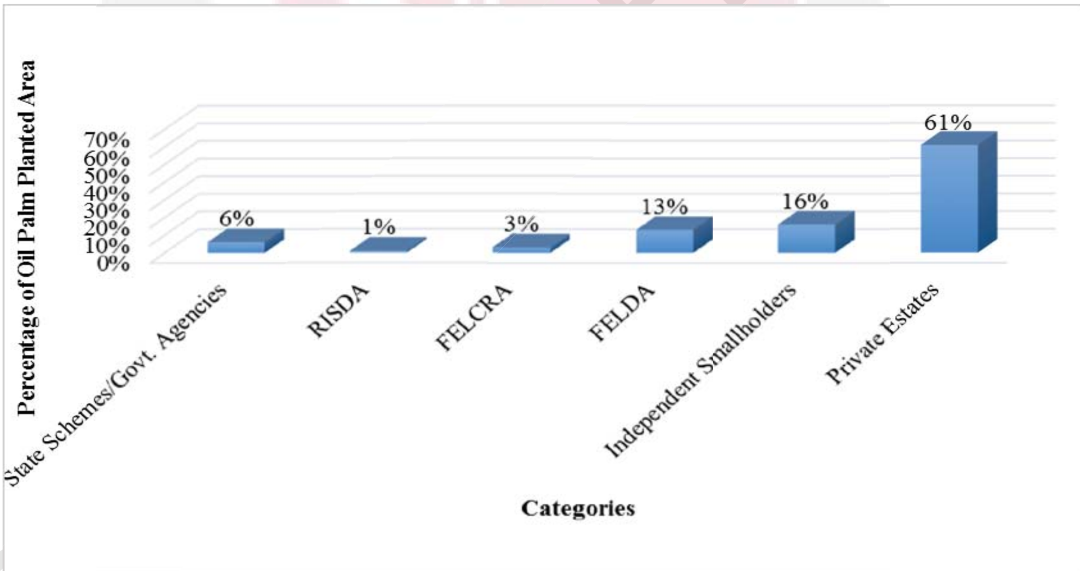

Figure 1.10 : Category of Malaysian Oil Palm Planted Area (ha) (Source: MPOB (2015))

In 2014, the cumulative land area of oil palm plantations in Malaysia reached approximately 5.39 million hectares and accounted for about 33 per cent of the world oil palm cultivated area (Basiron, 2014 in Sundram *et al.*, 2015; Basiron, 2012), out of this, Peninsula Malaysia accounts for 2,617,334,000 hectares while 2,774,901,000 hectares was accounted by Sabah and Sarawak (MPOB, 2014), see figure 1. 11.The independent oil palm smallholders owned total oil palm planted area of 883,3004 hectares in Malaysia where Johor accounts for 207,483.24 (23.50%) of the total planted area followed by Perak with 109,994.81 (12.46%) in Peninsula

Malaysia and Sabah with 217,402.72(24.62%) (MPOB, 2015) see figure 1.12 and 1.13. The oil palm planted area by independent smallholders within Johor State according to district indicates that Kluang have the highest with 45, 947.39 hectares followed by BatuPahat (37, 605.73), Muar (28, 763.90) and Pontain (28, 676.09) (MPOB, 2016), see figure 1. 14.

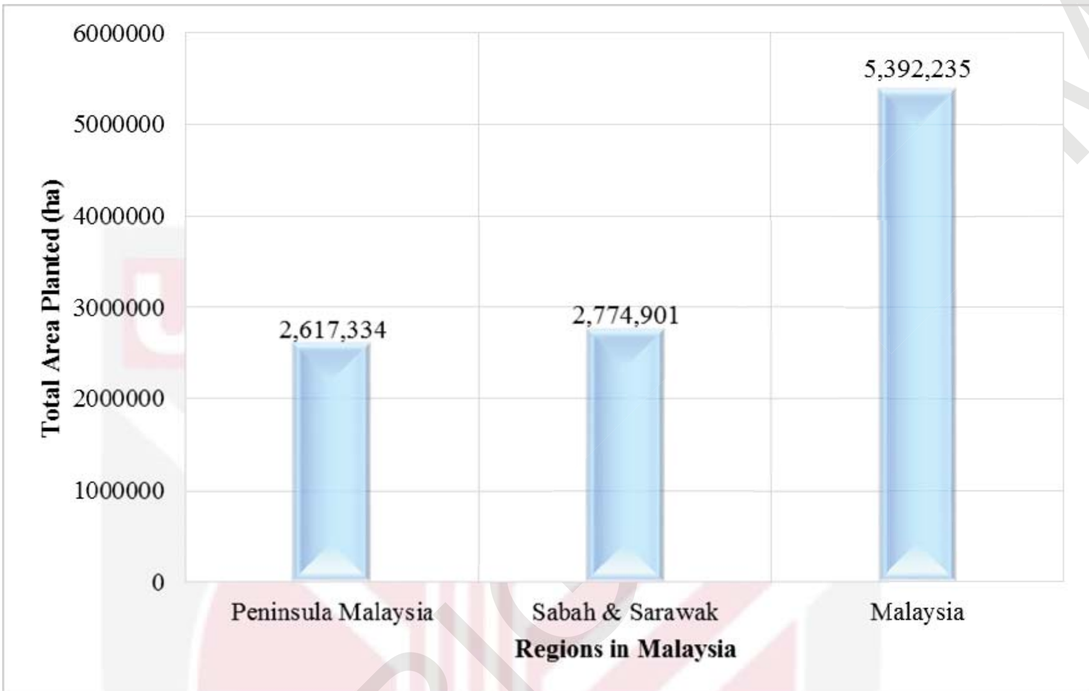

Figure 1.11 : Malaysian Total Oil Palm Planted Area according to Region (ha)
(Source: MPOB (2014))

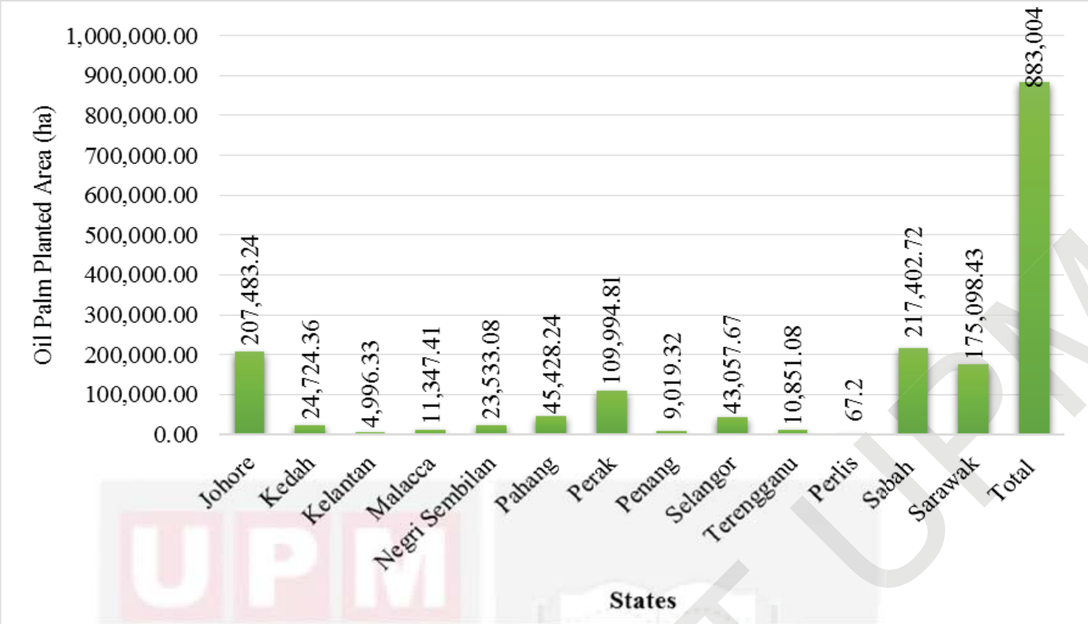

Figure 1.12 : Independent Oil Palm Smallholders Planted Area in Malaysia According to States (ha) (Source: MPOB (2015))

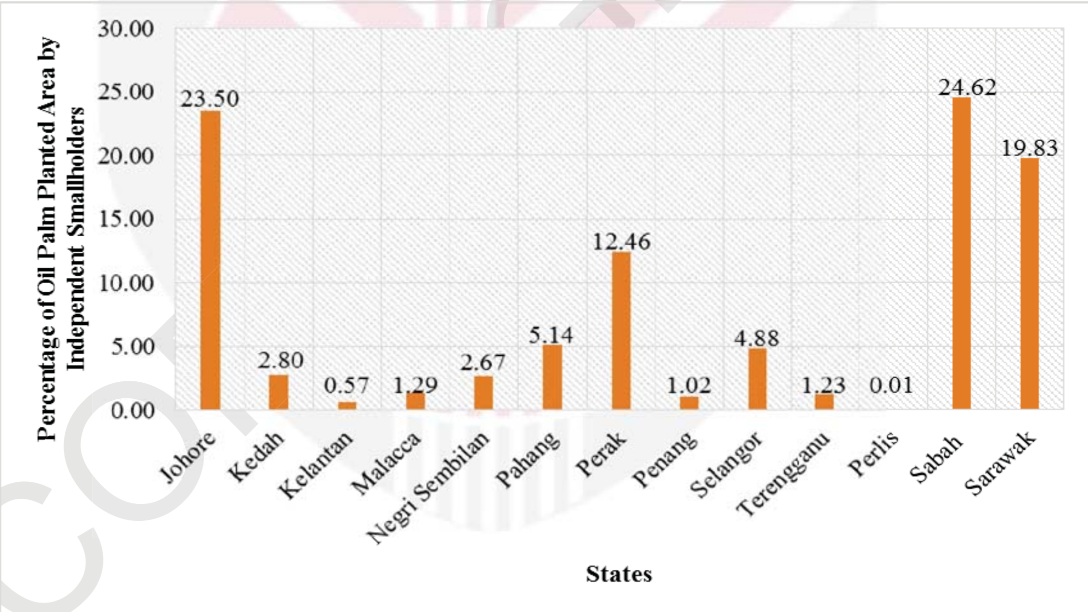

Figure 1.13 : Percent Distribution of Planted Area by Independent Oil Palm Smallholders in Malaysia According to States (ha)
(Source: MPOB (2015))

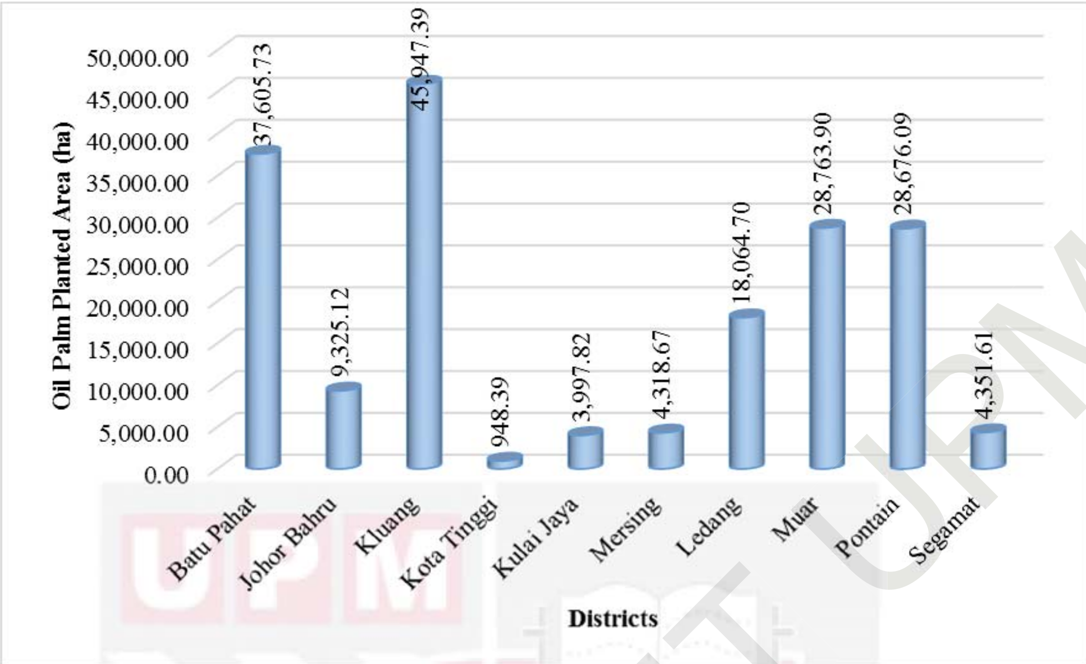

Figure 1.14 : Oil Palm Planted Area by Independent Smallholders in Johor According to District (ha) (Source: MPOB (2016))

According to Aikanathan, Basiron, Sundram, Chenayah, & Sasekumar (2015), about 1.5 million estimated smallholders cultivate oil palms in Malaysia and Indonesia. Malaysia alone employs about 600,000 people directly in the oil palm sub-sector, in addition to a significant number of people engaged in related industries (MPOC, 2014). There are 221,487 estimated total number of independent oil palm smallholders in Malaysia with Johor having the highest of 69,622 (31.43%) followed by Perak 38,742 (17.49%) and Selangor 19,801 (8.947%) in the Peninsula Malaysia (MPOB, 2015), see figure 1. 15 and 1. 16. The highest number of independent oil palm smallholders was found in Muar district with 18,008(25.14%) followed by BatuPahat and Kluang with 16,412 (22.91%) and 13,838 (19.32%) respectively (MPOB, 2016), see figures 1. 17 and 1. 18.

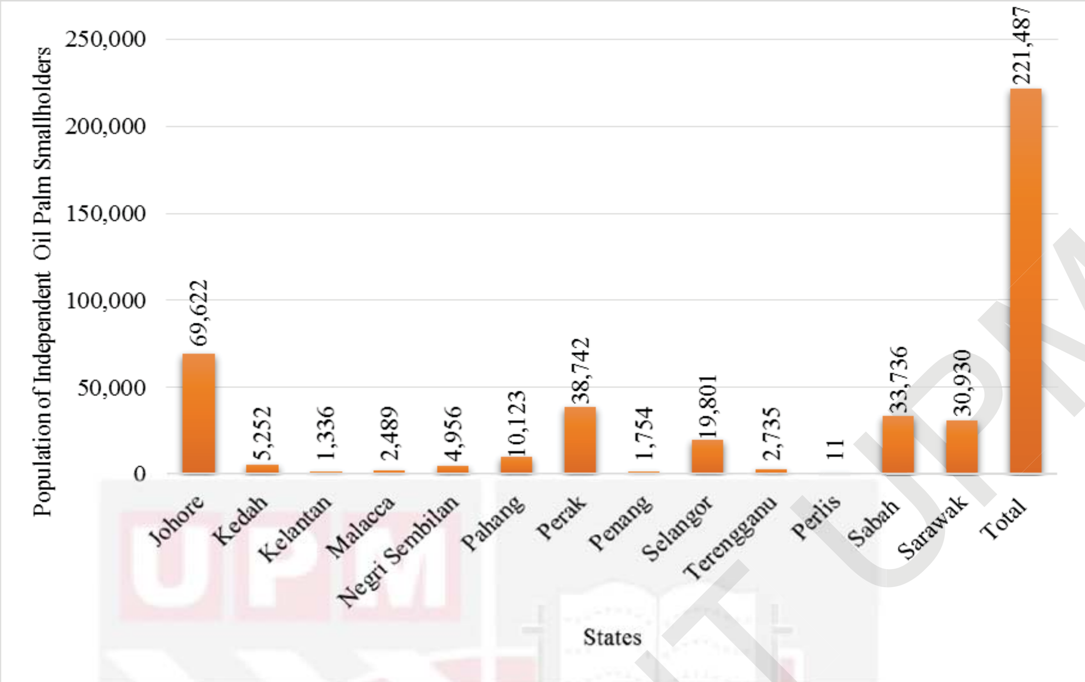

Figure 1.15 : Population of Independent Oil Palm Smallholders in Malaysia According to States (Source: MPOB (2015))

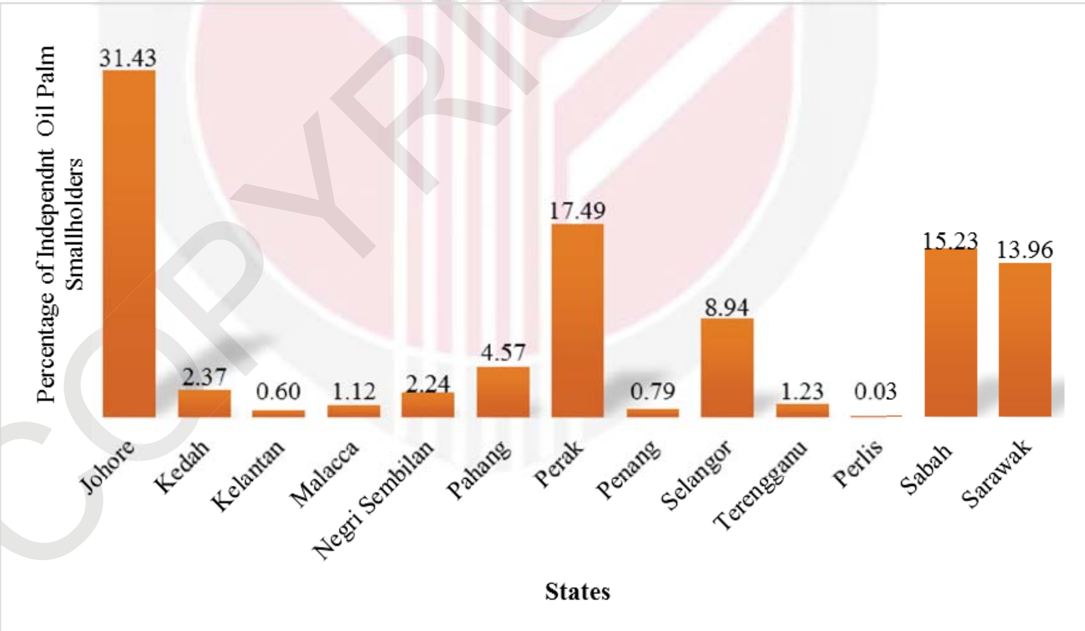

Figure 1.16 : Percent Distribution of Independent Oil Palm Smallholders in Malaysia According to States (Source: MPOB (2015))

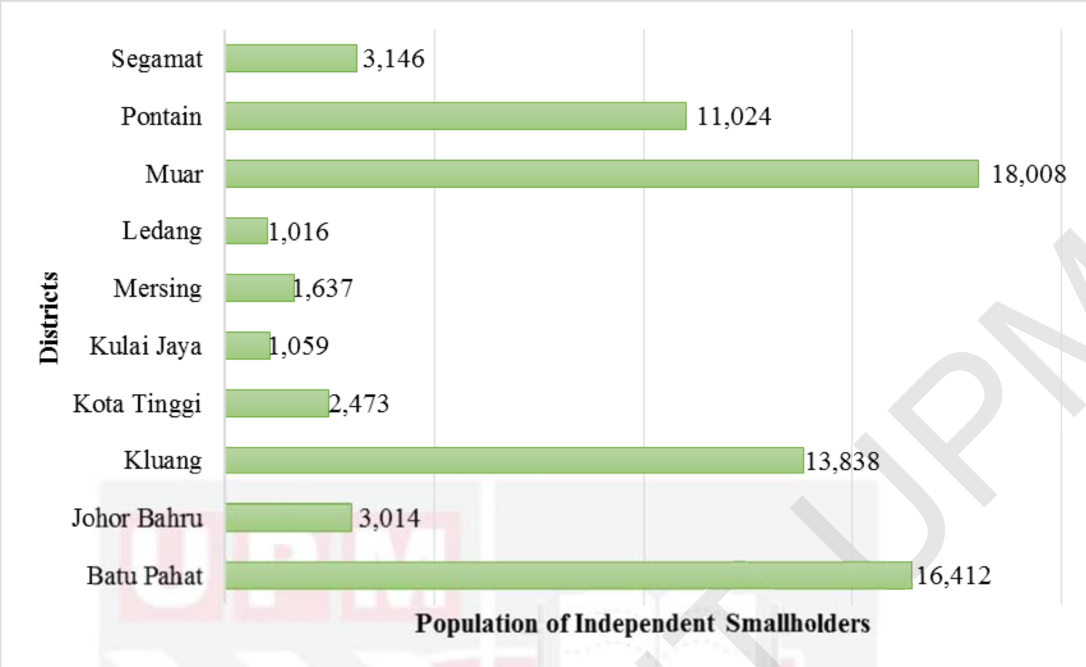

Figure 1.17 : Population of Independent Oil Palm Smallholders in Johor According to District (Source: MPOB (2016))

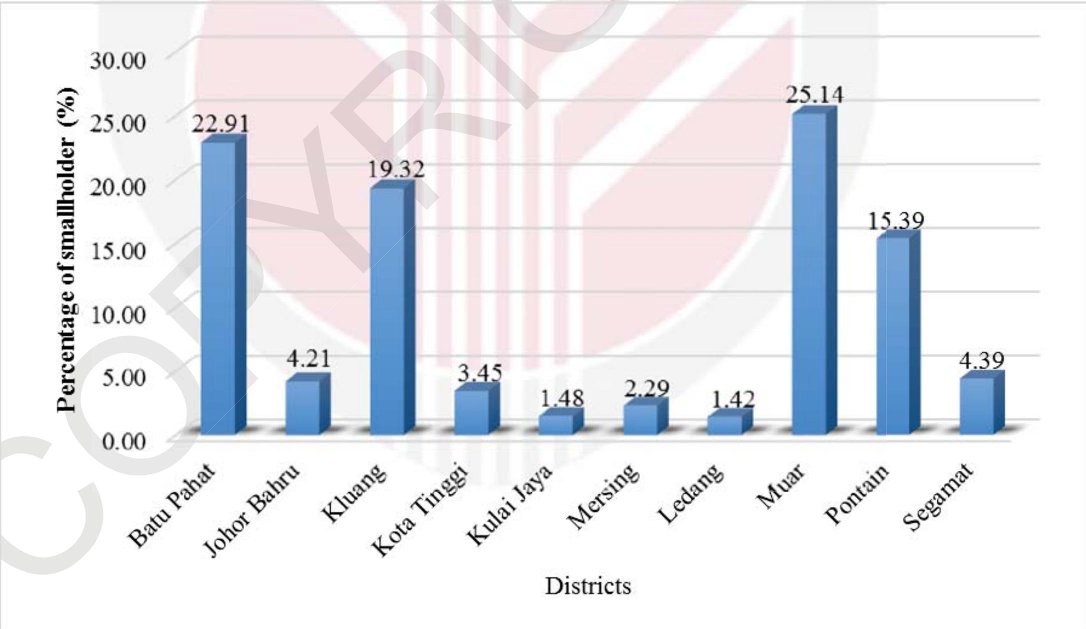

Figure 1.18 : Percent Distribution of Independent Oil Palm Smallholders in Johor According to District (Source: MPOB (2016))

Increased and productivity led growth of the agricultural sector could be the panacea that will bring structural change and compel the smallholder sub-sector's output and productivity increase in Malaysia. According to Al-hassan (2008), improved technical efficiency would facilitate increase use of farm resources by farmers and provide course for the adjustment necessary over time to attain sustainable crop such as palm oil production. The resource allocative efficiency of farmers has an extreme attaining effect on the observed level of farm output even with small farm sizes. The existence of shortfall in efficiency implies that farm output would be increased without the use of additional conventional farm inputs and improved technologies. Furthermore, efficiency measurement is a vital instrument in determining the magnitudes of the gains that could be achieved by adopting improved farm practice in agricultural production with a given level of technology (Laha & Kuri, 2011; Armagan, 2008; Rahman, 2003; Tauer, 2001; Zhu, 2000).

According to Ismail & Mamat (2002), Alam *et al.* (2015) and Michael (2012), the nature of the oil palm production cycle can generally be divided into three phases: (i) a non-productive phase lasting three years after planting, (ii) a period of steadily rising yield reaching a peak and (iii) a period of declining yield. The last phase of the cycle is associated with increased production costs and declining profit. They further noted in their study that oil palm can be maintained and harvested up to the age of 32 years, after which, harvesting is not easy because of the height problem and the oil palm become more prone to pests attack and diseases after the peak yield. Encouraging increase in agricultural production particularly in the oil palm industry is a strategic goal of the Malaysian government. ‘’The smallholders mostly apply smaller amount of farm inputs than they would if they maximized anticipated profits. The smallholders in some cases do not use or only partly use improved innovations, even when these improved innovations would provide more revenues on labour and land than some pre-existing technologies’’ (Guttormsen & Roll, 2014). Efficiency measurement in agricultural crop production reveals the level of farmers’ efficiency in inputs use and other farming activities (Khai & Yabe, 2011). Farmers in developing countries find it difficult to make use of all the potentials in new technologies and other farm resources, rendering them to be inefficient in farm decision making. Furthermore, efficiency in the utilization of scarce resources by farmers to increase their agricultural productivity and the need for sustained empirical studies to assess the extent and sources of inefficiency among smallholder oil palm farm households is a herculean task. This study therefore measured technical efficiency associated with production inputs according to crop age among oil palm smallholders in Johor, Malaysia.

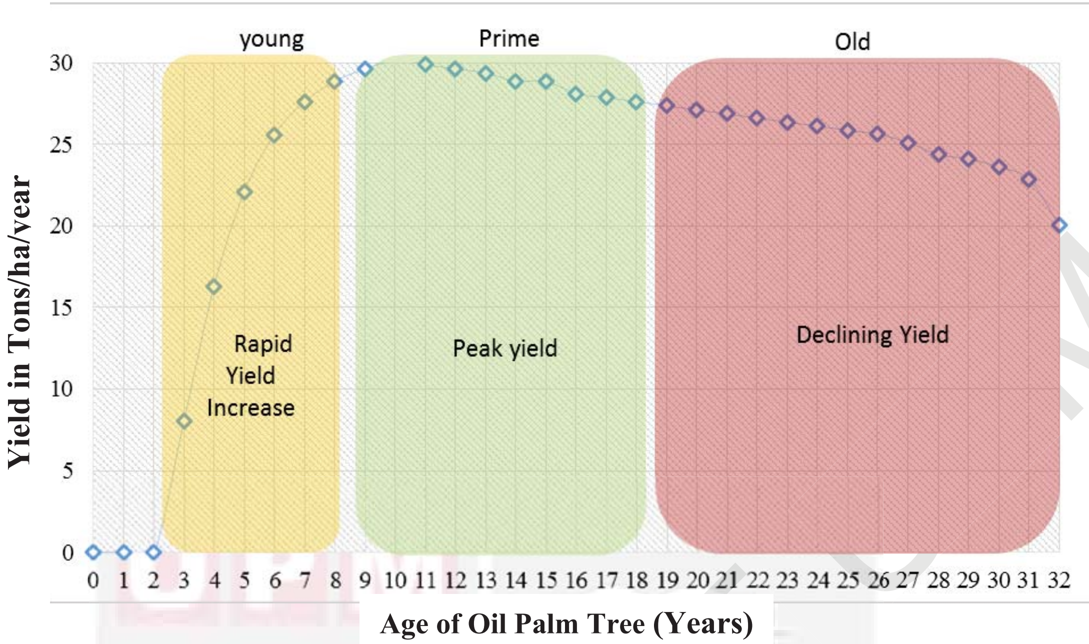

Figure 1.19 : Malaysia's Oil Palm Age and Yield Profile
(Source: Data obtained from Ismail & Mamat (2002) as adapted by Alam, Er & Begum (2015) and Michael (2012))

The Oil palm tree starts producing fruits after 3 years of planting in the field and would stay fruitful for the next 30 years or more. Oil palm trees planted in Malaysia are predominantly the *tenera* variety, which is a crossbreed between the *dura* and *pisifera*. The *tenera* variety produces 4 to 5 tons of crude palm oil and about 1 ton of palm kernels per hectare per year. The age profile of Malaysian oil palm fall into three categories based on the life cycle of the palm trees (see figure 1. 19). The production life span of oil palm starts with a non-productive phase lasting three years after planting and a period of rapid yield increase. At this phase, the crop age is <9years and it produces an average of 4.52 to 19.83 tons per year. This phase of crop age is regarded as the young category. The second crop age category is the period of steadily rising yield reaching a peak between the ages of 9 to 18 years. According to Alam, Er & Begum (2015) and Michael (2012), the peak yield of oil palm tree is between the ages of 9 to 18 years. This phase is therefore the prime stage that produces an average of 20.34 to 19.08 tons per year. The third crop age category is the period of diminishing yield between the ages of 19years and above. This phase is regarded as the old crop age and it produces an average of 18.83 tons to less than 12.18 tons per year. The old phase is last age category of the oil palm life cycle and it is related with increased costs of production and decreasing revenue.

1.2 Statement of the Problem

Efficiency measurement was introduced by Farrell (1957), known as technical competence. This efficiency is determined through efficiency score for each firm. Firms could be analyzed and evaluated and then compared with suitable corresponding firm. There is scope for additional increase in smallholders palm oil output from existing hectares, if resources are properly harnessed and efficiently allocated. Hence, this study becomes crucial in examining the technical efficiency associated with production inputs according to crop age among oil palm smallholders in Johor, Malaysia. Since increased output and productivity are directly related to production efficiency (Amaza & Olayemi, 2002). According to Damodaran (2010), oil palm smallholders' output can be improved using new technologies and modern agricultural farm practices. The oil palm smallholders under FELDA, RISDA and FELCRA are anticipated to increase the existing production levels of less than 3.5 tons to 4.0 tons while the current production is about 20 per cent of its theoretical potential oil palm yield of over 17 to 18 tons per hectare (Damodaran, 2010) (Figure 1. 20). The oil palm theoretical target yield has therefore not been achieved in the independent smallholder sub-sector in Malaysia.

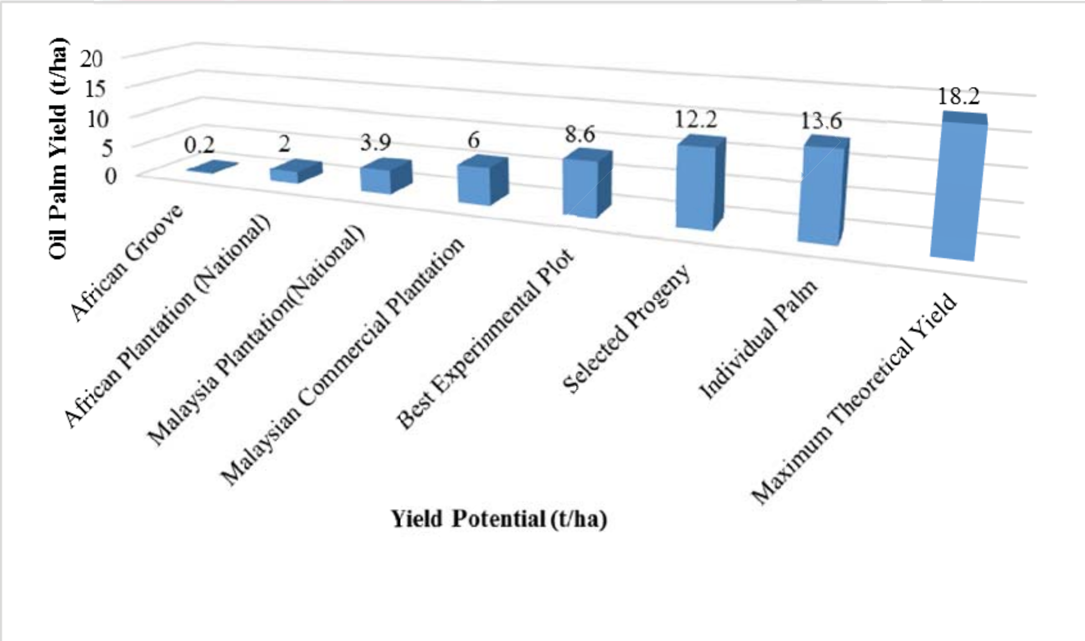

Figure 1.20 : Yield Potential of Palm Oil (MT t/ha) (Source: Corly (1998))

Malaysia is encountering the problem of inadequate skilled and unskilled labour in the plantations, evaluated at 20 percent of the total industry workforce (Azmi & Nagiah, 2013). This is because of the high desire of work in the estates and the increasing amount of lucrative job opportunity in other industries. Moreover, absences of mechanization alternatives in plantations make an over dependence on manual labour for all key farm activities such as fertilizing, harvesting, gathering and transportation, these affects the smallholders production efficiency. Thus, Malaysian oil palm plantations are intensely reliant on foreign workers which are presently evaluated at 80 percent of total the industry workforce. These foreign laborers send about 60 percent of their wages over to their nations. A Malaysian smallholder produces about 17 tons of fresh fruit brunches yearly, compared to the national average of about 21 tons. According to Rahman *et al.* (2008), the smallholders in Malaysia are less efficient than other producers, because of their small sized plot of 4 ha, poor agricultural practices e. g. use of low quality seedlings, having old palm trees, inadequate application of fertilizer and harvesting immature fresh fruit brunches.

According to Wissler (2015), smallholders that completed the speedy shift from subsistence farming to oil palm production moved into an agronomy which they had little knowledge about. In addition, they lacked training, education and spoken history which results to inefficient and high-input farming practices. Through more efficient use of land, labour and fertilizers the smallholders could possibly upsurge their output. But several smallholders do not have the means to finance in order to widen their revenue margins. The ad hoc attitudes to oil palm farming had contributed to shockingly low yields among the smallholder sub-sector. According to Lee *et al.* (2014) and Wissler (2015), oil palm smallholders' average yield per hectare remains histrionically lower than that of large plantations and also the independent smallholders that operate lacking assistance from private organizations or the government fetch a smaller amount of revenue. According to Wissler (2015) the smallholder's lower yield usually fallouts from inadequate use of fertilizer, selection of planting materials and premature picking of FFB, signifying poor understanding of efficient farming practices which restrained the smallholders' production efficiency (Teoh, 2010; Lee, Ghazoul, Obidzinski & Koh, 2014). In addition, inadequate application of fertilizer can affect the size and amount of FFB produced.

Presently, larger proportion of total oil palm area in Malaysia were filled by palm trees aged between 9 and 28 and plus whereas about 26 percent have cross over the peak yielding age (Alam, Er & Begum, 2015). The life span of the oil palm is roughly 22-25 years, it is mostly productive between the ages of 8 and 15, with its peak yield between the ages of 9 to 18, from then on; its yield continuously declining Fig. 1. 21 (United States Department of Agriculture USDA, 2011; Alam, Er & Begum, 2015; Michael, 2012; Ismail & Mamat, 2002). In 2012, about 65 percent of Malaysia's total oil palm areas were between the ages of 9 to 28 plus, while 26 percent are between 20 to 28 plus years age old (MPOB, 2012). These shows that the larger proportions of oil palm trees have exceeded the peak yielding years with varying crop ages and the expected potential reduction in oil palm fresh fruits brunches (FFB) yield would continue to affect national average yield growth. Despite the Malaysian government's effort for replanting oil palm trees, smallholders resist due to the 3-4years of non-income after replant.

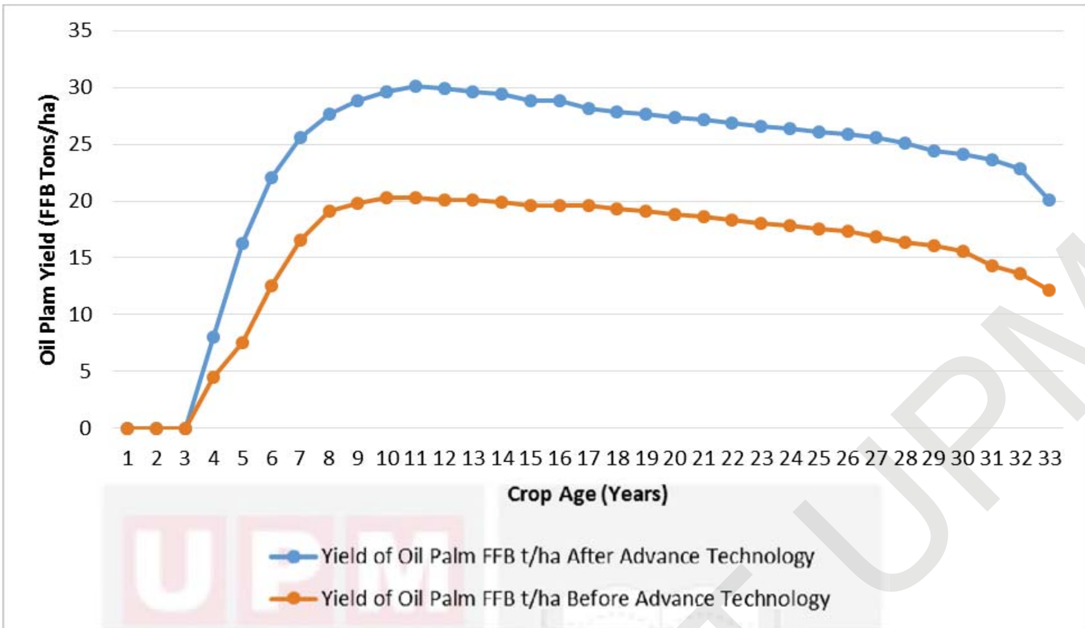

Figure 1.21 : Oil Palm Yield FFB t/ha according to Age of Crop before & After Technology Advancement in Malaysia
(Source: Adapted from Ismail & Mamat (2002))

The analyses carried out in this study were beyond most of the published literature concerning efficiency measurement in Johor, Malaysia. Since most of the efficiency researches on oil palm or other perennial crops in Malaysia or elsewhere did not account for crop age profile. Earlier studies on technical, allocative and economic efficiency among oil palm smallholders were all carried out on aggregated data analysis. Efficiency estimates from these studies were subject to data aggregation bias, since yield variation in oil palm is across crop age. Efficiency measurement among perennial crop smallholders without consideration to crop age provide only a partial measure of efficiency and inferences may not reveal the specific smallholders crop age category. The smallholder oil palm farms that are found to be relatively inefficient would be made to improve so that farmers will be efficient in resource use. To the best of my knowledge there appears to be no existing study on technical, allocative and economic efficiency measurements according to oil palm crop age in Johor, Malaysia or elsewhere. It was against this backdrop that this study was conceptualized to estimate technical efficiency associated with production inputs according to crop age among oil palm smallholders in Johor, Malaysia to bridge the gap in existing literature on efficiency research.

1.3 Objectives of the Study

The main objective of the study was to measure technical efficiency associated with production inputs according to crop age among oil palm smallholders in Johor, Malaysia. The specific objectives were to:

i. Examine the socio-economic characteristics of the oil palm smallholders according to crop age;
ii. Estimate and compare the level of technical, allocative and economic efficiencies of oil palm smallholders according to crop age;
iii. Estimate and compare the performances of the Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and Parametric Full Frontier (PFF) using Corrected Ordinary Least Square (COLS) in measuring the technical efficiency of oil palm smallholders according to crop age;
iv. Examine the determinants of technical, allocative and economic inefficiencies among oil palm smallholders according to crop age; and
v. Identify the production problems encountered by oil palm smallholders according to crop age in Johor, Malaysia.

1.4 Significance of the Study

This study would assist oil palm smallholders in increasing their income, productivity and efficiency in resources use that will result in attaining the current Malaysia's commercialization desires. And it would contribute to the overall development of the agricultural industry and the nation as a whole. The finding of this study is slightly more technical because it stratified the smallholders according to the age of their crops. It can therefore, be used as an advisory report for the advancement of the Agricultural sub-sector and bridge the gap in existing literature on technical efficiency associated with production inputs among oil palm smallholders in Johor, Malaysia. Based on findings obtained, the study would determine amount of inputs which need to be given much emphasis and thus further improvement to minimize wastages of resources by the smallholders.

The results of this study would contain important policy implications, thus the evidence of enhanced technical, allocative and economic efficiencies suggests that there are prospects for oil palm smallholders to increase production and efficiency in resources use. The study would also make numerous important contributions to the literature amongst these are: first of all, it was the pioneer study to investigate the possible technical, allocative and economic efficiencies differential associated with crop age profile among oil palm smallholders in Johor, Malaysia. And Secondly, It was the first study to apply and compare Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and Parametric Full Frontier (PFF) approaches to measure technical, allocative and economic efficiencies according to crop age among oil palm smallholders in the study area. The findings of study would be found relevant material for researchers and students who may carry out further studies on technical efficiency among oil palm smallholders according to crop age within and outside Johor. The study would also provide the policymakers with information to design programmes that can contribute to measures needed to expand the agricultural production potentials of Malaysia, particularly in the smallholders sub-sector. The result of this study would also be very useful to agricultural extension workers, planners and for the oil palm smallholders who are the decision-makers on the farm.

1.5 Statement of Research Hypothesis

The following hypotheses were postulated for testing:

Table 1.1 : Representation of the Research Hypothesis

Null Hypotheses
i. H_0: $\mu = 0$
a) mean technical efficiency (TE) based on crop age categories
b) mean allocative efficiency (AE) based on crop age categories
c) mean economic efficiency (EE) based on crop age categories
ii. H_0: $\gamma = 0$
H_0: $\sigma^2 = 0$ i.e. $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0$
iii. H_0: $\delta_1 = \delta_2 = \delta_3 = \ldots = \delta_{17} = 0$
iv. H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \ldots.. = \alpha_{17} = 0$
H_0: $\delta_1 = \delta_2 = \delta_3 = \ldots\ldots = \delta_{17} = 0$

The hypotheses stated above were operationalized as follows:

Hypothesis i (H0): There is no significant difference in the level technical, allocative and economic efficiencies of oil palm smallholders based on young, prime and old crop age categories;

Hypothesis ii. (H0): There is no existence of Stochastic Frontier in the oil palm smallholder's Cobb-Douglass production function according to crop age;

Hypothesis iii. (H0): There is no technical inefficiency effects in the Cobb-Douglas Stochastic Frontier production function model of the oil palm smallholders according to crop age;

Hypothesis iv. (H0): The socio-economic, institutional and other determinants have no influence on technical, allocative and economic inefficiencies of oil palm smallholders according to crop age.

1.6 Scope of the Study

The target populations were the independent oil palm smallholders in the State of Johor, Malaysia. The study employed DEA to estimate technical, allocative and economic efficiencies and compared with the estimates from SFA and PFF using Corrected Ordinary Least Square (COLS) according to crop age. It relied on primary data that was collected in 2015 production year from the independent oil palm smallholders according to crop age for its analysis.

1.7 Organization of the Study

This study on technical efficiency associated with production inputs according to crop age among oil palm smallholders in Johor, Malaysia is organized into five separate chapters. Chapter 1 dwelled on introduction of the study where emphasis were on overview of Malaysia's agriculture with regards to oil palm production, export, oil palm planted areas and population distribution of smallholders. It also presented the statement of research problem, objectives and significance of the study, research hypotheses, scope and organization of the study.Chapter 2 presented review of empirical studies on technical, allocative and economics efficiency as well as methodological issues and challenges faced by smallholders. Chapter 3 focused on conceptual framework for oil palm production efficiency according to crop age, Farrell's concept of technical, allocative and economic efficiency, theoretical framework based on DEA, SFA, PFF using COLS, robust efficiency estimators such as FDH, Order-alpha, Order-m and DEA-bootstrap estimator. It also described theoretical framework for Tobit and OLS regression models. It also shows the study area, sources and method of data collection, validation of instrument for data collection, nature of data used for the study, sampling techniques, *a priori* expectation of the signs of the variables and the analytical techniques.

Chapter 4 presented results and discussion based on the socio-economic characteristics of the oil palm smallholders, detection of outliers in data and diagnostic statistics, summary of descriptive statistics of data used for the analyses, output/inputs and inputs prices, determinants of inefficiency, estimates of technical, allocative and economic efficiencies based on DEA, SFA, PFF using COLS, FDH, order-alpha, Order-m estimators and the output and inputs slacks based on DEA estimator according to crop age. This chapter also presented results and discussion based on DEA-bootstrap estimator, hypotheses testing for mean difference in technical, allocative and economic efficiencies, Maximum Likelihood estimates of Cobb-Douglas Stochastic Frontier production, estimated elasticities of inputs and return to scale (RTS), Maximum Likelihood estimates of the determinants of technical inefficiency, generalized likelihood ratio test of the Cobb-Douglas Stochastic Frontier production function, Tobit and OLS estimation of determinants of technical, allocative and economic inefficiency. This chapter also presented the production problems encountered by oil palm smallholders according to crop age. Chapter 5 presented the summary, implications of the study for policy, recommendations for policy measures, limitations and suggestions for future study and conclusion followed by the references and appendices.

REFERENCES

Abatania, L. N., Hailu, A., & Mugera, A. W. (2012, February). Analysis of farm household technical efficiency in Northern Ghana using bootstrap DEA. In *56th Annual Conference of the Australian Agricultural and Resource Economics Society*.

Abdulai, A., & Huffman, W. E. (1998). *An examination of profit inefficiency of rice farmers in Northern Ghana*. Iowa State University, Department of Economics.

Adesina, A. A., & Chianu, J. (2002). Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. *Agroforestry systems*, *55* (2), 99-112.

Adhikari, C. B., & Bjorndal, T. (2012). Analyses of technical efficiency using SDF and DEA models: evidence from Nepalese agriculture. *Applied Economics*, *44*(25), 3297-3308.

Aigner, D. J., & Chu, S. F. (1968). On estimating the industry production function. *The American Economic Review*, *58*(4), 826-839.

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21-37.

Aikanathan, S., Basiron, Y., Sundram, K., Chenayah, S., & Sasekumar, A. (2015). Sustainable management of oil palm plantation industry and the perception implications. *Journal of Oil Palm, Environment & Health*, *6*, 10-24.

Ajibefun, I. A., & Aderinola, E. (2003). Determinants of Technical Efficiency and Policy Implications in Traditional Agricultural Production. In *Empirical Study of Food Crop Farmers "Work in Progress Report Presented at the Bi Annual Research Workshop of AERC*.

Ajibefun, I. A., Battese, G. E., & Kada, R. (1996). *Technical Efficiency and Technological Change in the Japanese Rice Industry: a Stochastic Frontier Analysis. Centre for Efficiency and Productivity Analysis (CEPA)*. Working Paper 9/96. University of New England.

Alam, A. F., Er, A. C., & Begum, H. (2015). Malaysian oil palm industry: prospect and problem. *Journal of Food, Agriculture & Environment*, *13*(2), 143-148.

Alene, A. D., & Hassan, R. M. (2008). Efficiency of food production under old and new technology: The case of farmers within and outside the Extension Package Program in Ethiopia. *The Journal of Developing Areas*,*41*(2), 233-249.

Alene, A. D., Manyong, V. M., & Gockowski, J. (2006). The production efficiency of intercropping annual and perennial crops in southern Ethiopia: A comparison of distance functions and production frontiers. *Agricultural systems*, *91*(1), 51-70.

Al-Hassan, S. (2008). *Technical efficiency of rice farmers in Northern Ghana* (No. RP_178). African Economic Research Consortium.

Ali, A. I., Lerme, C. S., & Seiford, L. M. (1995). Components of efficiency evaluation in data envelopment analysis. *European Journal of Operational Research*, *80*(3), 462-473.

Alwarritzi, W., Nanseki, T., & Chomei, Y. (2015). Analysis of the factors influencing the technical efficiency among oil palm smallholder farmers in Indonesia. *Procedia Environmental Sciences*, *28*, 630-638.

Amaza, P. S., & Maurice, D. C. (2005). Identification of factors that influence technical efficiency in rice-based production systems in Nigeria. *Rice Policy and Food Security in sub-Saharan Africa*, 70.

Amaza, P. S., & Olayemi, J. K. (2002). Analysis of technical inefficiency in food crop production in Gombe State, Nigeria. *Applied Economics Letters*,*9*(1), 51-54.

Amodu, M. Y., Owolabi, J. O., & Adeola, S. S. (2011). Resource use efficiency in part-time food crop production: The stochastic frontier approach.*Nigerian Journal of Basic and Applied Sciences*, *19*(1).

Amudavi, D. M., Khan, Z. R., Wanyama, J. M., Midega, C. A. O., Pittchar, J., Nyangau, I. M., ... & Pickett, J. A. (2009). Assessment of technical efficiency of farmer teachers in the uptake and dissemination of push–pull technology in Western Kenya. *Crop Protection*, *28*(11), 987-996.

Armagan, G. (2008). Determining the factors affecting efficiency scores in agriculture. *International Journal of Agricultural Research*, *3*(4), 325-330.

Asmild, M., & Hougaard, J. L. (2006). Economic versus environmental improvement potentials of Danish pig farms. *Agricultural Economics*, *35*(2), 171-181.

Asogwa, B. C., Penda, S. T., & Lawal, W. L. (2011). Application of Data Envelopment Analysis to Evaluate Farm Resource Management of Nigerian Farmers. *Journal of Agricultural science*, *2*(1), 9-15.

Atkinson, S. E., & Wilson, P. W. (1995). Comparing mean efficiency and productivity scores from small samples: a bootstrap methodology. *Journal of Productivity Analysis*, *6*(2), 137-152.

Azadeh, A., Ghaderi, S. F., Omrani, H., & Eivazy, H. (2009). An integrated DEA–COLS–SFA algorithm for optimization and policy making of electricity distribution units. *Energy Policy*, *37*(7), 2605-2618.

Azmi, R., & Nagiah, C. (2013). A review of smallholder oil palm production: challenges and opportunities for enhancing sustainability-a Malaysian perspective. *Journal of Oil Palm, Environment and Health (JOPEH)*, *3*.

Bakhsh, K. (2007). *An analysis of technical efficiency and profitability of growing potato, carrot, radish and bitter gourd: a case study of Pakistani Punjab* (Doctoral dissertation, University of Agriculture Faisalabad).

Balaguer-Coll, M. T., Prior, D., & Tortosa-Ausina, E. (2007). On the determinants of local government performance: A two-stage nonparametric approach. *European Economic Review*, *51*(2), 425-451.

Balcombe, K., Fraser, I., Latruffe, L., Rahman, M., & Smith, L. (2008). An application of the DEA double bootstrap to examine sources of efficiency in Bangladesh rice farming. *Applied Economics*, *40*(15), 1919-1925.

Baležentis, T., Kriščiukaitienė, I., & Baležentis, A. (2014). A nonparametric analysis of the determinants of family farm efficiency dynamics in Lithuania. *Agricultural Economics*, *45*(5), 589-599.

Basiron, Y. (2012). A Fair Trade Approach for Promoting Food Security and Ensuring Supply Sustainability in Oils & Fats Trade. *Journal of Oil Palm, Environment and Health (JOPEH)*, *2*.

Basiron, Y. (2014). Palm oil industry transformation: Techno-ecological economic perspectives. A presentation made at the International Palm Oil Sustainability Conference, Kota Kinabalu Malaysia.

Battese, G. E. (1992). Frontier production functions and technical efficiency: a survey of empirical applications in agricultural economics. *Agricultural economics*, *7*(3), 185-208.

Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. In *International Applications of Productivity and Efficiency Analysis* (pp. 149-165). Springer Netherlands.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics*, *20*(2), 325-332.

Battese, G. E., Malik, S. J., & Gill, M. A. (1996). An investigation of technical inefficiencies of production of wheat farmers in four districts of Pakistan. *Journal of Agricultural Economics*, *47*(1-4), 37-49.

Bhatt, M. S., & Bhat, S. A. (2014). Technical Efficiency and Farm Size Productivity-Micro Level Evidence From Jammu & Kashmir. *International Journal of Food and Agricultural Economics*, *2*(4), 27.

Bifarin, J. O., Alimi, T., Baruwa, O. I., & Ajewole, O. C. (2008, October). Determinant of technical, allocative and economic efficiencies in the plantain (Musa spp.) production industry, Ondo State, Nigeria. In *IV International Symposium on Banana: International Conference on Banana and Plantain in Africa: Harnessing International 879* (pp. 199-209).

Binam, J. N., Tonye, J., Nyambi, G., & Akoa, M. (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food Policy*, *29*(5), 531-545.

Boame, A. K. (2004). The technical efficiency of Canadian urban transit systems. *Transportation Research Part E: Logistics and Transportation Review*, *40*(5), 401-416.

Bogetoft, P., & Otto, L. (2011). International Series in Operations Research & Management Science: Benchmarking with DEA, SFA, and R.

Bozoğlu, M., & Ceyhan, V. (2007). Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun province, Turkey. *Agricultural systems*, *94*(3), 649-656.

Brandi, C. (2013). *Sustainability certification in the Indonesian palm oil sector: benefits and challenges for smallholders*. Dt. Inst. für Entwicklungspolitik.

Brandi, C., Cabani, T., Hosang, C., Schirmbeck, S., Westermann, L., & Wiese, H. (2015). Sustainability standards for palm oil: Challenges for smallholder certification under the RSPO. *The Journal of Environment & Development*, *24*(3), 292-314.

Bravo-Ureta, B. E., & Evenson, R. E. (1994). Efficiency in agricultural production: the case of peasant farmers in eastern Paraguay. *Agricultural economics*, *10*(1), 27-37.

Bravo-Ureta, B. E., & Pinheiro, A. E. (1997). Technical, economic, and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The Developing Economies*, *35*(1), 48-67.

Bravo-Ureta, B. E., & Rieger, L. (1990). Alternative production frontier methodologies and dairy farm efficiency. *Journal of Agricultural Economics*, *41*(2), 215-226.

Bravo-Ureta, B. E., & Rieger, L. (1991). Dairy farm efficiency measurement using stochastic frontiers and neoclassical duality. *American Journal of Agricultural Economics*, *73*(2), 421-428.

Brázdik, F. (2006). Non-parametric analysis of technical efficiency: Factors affecting efficiency of West Java rice farms. *CERGE-EI Working Paper Series*, (286).

Burki, A. A., & Terrell, D. (1998). Measuring production efficiency of small firms in Pakistan. *World Development*, *26*(1), 155-169.

Caldas, J. V., & Rebelo, J. (2000). Technical efficiency and productivity growth in the farming system of the Douro Region, Portugal: a stochastic frontier approach (SFA). *Desenvolvimento e Ruralidades no Espaço Europeu*, *1*, 91-108.

Cazals, C., Florens, J. P., & Simar, L. (2002). Non-parametric frontier estimation: A robust approach. *Journal of econometrics, 106*, 1-25.

Chander, P., Drèze, J., Lovell, C. K., & Mintz, J. (Eds.). (2007). *Public Goods, Environmental Externalities and Fiscal Competition: Selected Papers on Competition, Efficiency, and Cooperation in Public Economics by Henry Tulkens*. Springer Science & Business Media.

Chapman, L., Rodriguez, V. B., & Harrison, S. (1999). Productivity: Influence of resource quality on productivity of wool producing farms. *Australian Farm Surveys Report: Financial Performance of Australian Farms*, (1999), 37.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, *2*(6), 429-444.

Chimai, B. C. (2011). *Determinants of Technical Efficiency in Smallholder Sorghum Farming in Zambia* (Doctoral dissertation, The Ohio State University).

Coelli, T. J. (1995). Recent developments in frontier modelling and efficiency measurement. *Australian Journal of agricultural economics*, *39*(3), 219-245.

Coelli, T. J., Rao, D. P., O'Donnell, C. J., & Battese, G. E. (1998). An introduction to productivity and efficiency analysis. *Springer Science: New York*.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Coelli, T. J. (1996). *A Guide to Frontier Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation*. CEPA Working Paper, University of New England, Armidale.

Coelli, T., & Fleming, E. (2004). Diversification economies and specialisation efficiencies in a mixed food and coffee smallholder farming system in Papua New Guinea. *Agricultural Economics*, *31*(2-3), 229-239.

Coelli, T., & Perelman, S. (1996). *Efficiency measurement, multiple-output technologies and distance functions: With application to European Railways* (No. DP 1996/05). CREPP.

Coelli, T., & Perelman, S. (1999). A comparison of parametric and non-parametric distance functions: With application to European railways. *European journal of operational research*, *117*(2), 326-339.

Coelli, T., Rahman, S., & Thirtle, C. (2002). Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non-parametric Approach. *Journal of Agricultural Economics*, *53*(3), 607-626.

Colchester, M., & Chao, S. (2011). Oil Palm Expansion in South East Asia: an overview. *Oil Palm Expansion in South East Asia*, 1.

Collier, T., Johnson, A. L., & Ruggiero, J. (2011). Technical efficiency estimation with multiple inputs and multiple outputs using regression analysis. *European Journal of Operational Research*, *208*(2), 153-160.

Corbo, V., & De Melo, J. (1986). Measuring technical efficiency: A comparison of alternative methodologies with census data. In *Measurement issues and behavior of productivity variables* (pp. 1-39). Springer Netherlands.

Corley, R. H. V. (1998). What is the upper limit to oil extraction ratio?. In *International Conference on Oil and Kernel production in oil palm. A global perspective September 27-28Kuala Lumpur, Malaysia* (No. L-0372). PORIM.

Cubbin, J., & Tzanidakis, G. (1998). Regression versus data envelopment analysis for efficiency measurement: an application to the England and Wales regulated water industry. *Utilities Policy*, *7*(2), 75-85.

Da Silva, T., Martins-Filho, C., & Ribeiro, E. (2016). A comparison of nonparametric efficiency estimators: DEA, FDH, DEAC, FDHC, order-m and quantile. *Economics Bulletin*, *36*(1), 118-131.

Dakulah, A., & Othman, N. (2015). Principle component analysis on good agriculture practices among oil palm smallholders in Pontian Johor. *Research Journal of Agriculture and Biological Sciences*, *11*(2 Special), 1-6.

Damodaran, R. (2010). Smallholders Can Help Boost Palm Oil Yield, Business Times. The New Straits Times Press (Malaysia) Berhad, Balai Berita 31, Jalan Riong, 59100 Kuala Lumpur, Malaysia. rupabanerji@nstp.com.my

Daniel, A. I., Oyakhilomen, O., & Zibah, R. G. (2015). Technical Efficiency-Food Security Nexus in Kaduna State, Nigeria: A Case Study of Poultry Egg Farmers. *Consilience: The Journal of Sustainable Development*, *14*(2), 244-259.

Danso-Abbeam, G., Aidoo, R., & Ohene-Yankyera, K. A. K. (2012). Technical efficiency in Ghanas cocoa industry: Evidence from Bibiani-Anhwiaso-Bekwai District. *Journal of Development and Agricultural Economics*, *4*(10), 287-294.

Dantsis, T., Douma, C., Giourga, C., Loumou, A., & Polychronaki, E. A. (2010). A methodological approach to assess and compare the sustainability level of agricultural plant production systems. *Ecological indicators*, *10*(2), 256-263.

Daraio, C., & Simar, L. (2007). *Advanced Robust and nonparametric methods in efficiency analysis: methodology and applications*. Springer Science & Business Media.

De Borger, B., & Kerstens, K. (1996). Cost efficiency of Belgian local governments: A comparative analysis of FDH, DEA, and econometric approaches. *Regional Science and Urban Economics*, *26*(2), 145-170.

De Borger, B., Kerstens, K., Moesen, W., & Vanneste, J. (1994). A non-parametric free disposal hull (FDH) approach to technical efficiency: an illustration of radial and graph efficiency measures and some sensitivity results. *Swiss Journal of Economics and Statistics*, *130*(4), 647-667.

De Sousa, M. D. C. S., & Stošić, B. (2005). Technical efficiency of the Brazilian municipalities: correcting nonparametric frontier measurements for outliers. *Journal of Productivity analysis*, *24*(2), 157-181.

De Witte, K., & Marques, R. C. (2010). Influential observations in frontier models, a robust non-oriented approach to the water sector. *Annals of Operations Research*, *181*(1), 377-392.

de-Graft Acquah, H. (2014). Sensitivity of Technical Efficiency Estimates to Estimation Methods: An Empirical Comparison of Parametric and Non-Parametric Approaches. *APSTRACT: Applied Studies in Agribusiness and Commerce*, *8*(1).

Department of Statistics Malaysia (2016). Selected Agricultural Indicators, Malaysia. Department of Statistics, Malaysia. www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=72&bul_id=T2Z3NkhLSFk2VjZ5dkdUL1JQUGs4dz09&menu_id=Z0VTZGU1UHBUT1VJMFlpaXRRR0xpdz09 accessed on 3/03/2017

Deprins, D., & Simar, L. & Tulkens, H. (1984). Measuring Labor Efficiency in Post Offices. In Marchand M., P. Pestieau and H. Tulkens (eds.), The Performance of Public Enterprises: Concepts and Measurements.

Deprins, D., Simar, L., & Tulkens, H. (2006). Measuring labor-efficiency in post offices. In *Public goods, environmental externalities and fiscal competition* (pp. 285-309). Springer US.

Dhungana, B. R., Nuthall, P. L., & Nartea, G. V. (2004). Measuring the economic inefficiency of Nepalese rice farms using data envelopment analysis. *Australian Journal of Agricultural and Resource Economics*, *48*(2), 347-369.

Dolmatov, I. A., & Dvorkin, V. V. (2015). Parametric and Non-Parametric Cost Efficiency Benchmarking of Water Utilities in Russia. *Higher School of Economics Research Paper No. WP BRP*, *42*.

Economic Transformation Programme (ETP) (2012). Annual Report. Available from http//www.pmo.gov.my/dokumenattached/Eng_ETP2012_Full.pdf.assessed on 15 August 2014

Efron, B. (1979). Bootstrap methods: another look at the jackknife Annals of Statistics 7: 1–26. *View Article PubMed/NCBI Google Scholar*.

Encarta (2007). Encarta Premium Suite, World Interactive Atlas, Microsoft Internet Explorer.

Encyclopedia Britannica: School Library Subscribers Last updated 26/5/2016. https://global.britannica.com/place/Malaysia accssed on 26/7/2016.

Essilfie, F. L., Asiamah, M. T., & Nimoh, F. (2011). Estimation of farm level technical efficiency in small scale maize production in the Mfantseman Municipality in the Central Region of Ghana: A stochastic frontier approach. *Journal of Development and Agricultural Economics*, *3*(14), 645-654.

Etwire, P. M., Martey, E., & Dogbe, W. (2013). Technical efficiency of soybean farms and its determinants in Saboba and Chereponi Districts of Northern Ghana: a stochastic frontier approach. *Sustainable Agriculture Research*, *2*(4), 106.

Fadhilah, D. N., Karim, M., & Mother, M. M. (2010, December). Efficiency measurement of oil palm production by Jengka province under FELDA management by applying Data Envelopment Analysis-application of BCC model. In *Science and Social Research (CSSR), 2010 International Conference on* (pp. 489-493). IEEE.

Färe, R., & Grosskopf, S. (1995). Nonparametric tests of regularity, Farrell efficiency, and goodness-of-fit. *Journal of Econometrics*, *69*(2), 415-425.

Fare, R., Grosskopf, S., & Lovell, C. K. (1994). *Production frontiers*. Cambridge University Press.

Färe, R., Grosskopf, S., Lovell, C. K., & Pasurka, C. (1989). Multilateral productivity comparisons when some outputs are undesirable: a nonparametric approach. *The review of Economics and Statistics*, 90-98.

Färe, R., Grosskopf, S., Lovell, C. K., & Yaisawarng, S. (1993). Derivation of shadow prices for undesirable outputs: a distance function approach. *The review of economics and statistics*, 374-380.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, *120*(3), 253-290.

Featherstone, A. M., Langemeier, M. R., & Ismet, M. (1997). A nonparametric analysis of efficiency for a sample of Kansas beef cow farms. *Journal of Agricultural and Applied Economics*, *29*(01), 175-184.

Fleming, E., & Coelli, T. (2004). Assessing the performance of a nucleus estate and smallholder scheme for oil palm production in West Sumatra: a stochastic frontier analysis. *Agricultural Systems*, *79*(1), 17-30.

Fleming, E., & Lummani, J. (2001). Analysis of the technical efficiency of cocoa smallholders in the Gazelle Peninsula, East New Britain Province. *Occasional Paper*, *7*.

Fraser, I., & Hone, P. (2001). Farm-level efficiency and productivity measurement using panel data: wool production in south-west Victoria. *Australian Journal of Agricultural and Resource Economics*, *45*(2), 215-232.

Fuentes, R., Fuster, B., & Lillo-Bañuls, A. (2016). A three-stage DEA model to evaluate learning-teaching technical efficiency: Key performance indicators and contextual variables. *Expert Systems with Applications*, *48*, 89-99.

Gabdo, B. H. (2014). *Efficiency of Livestock-Oil Palm Integration under Smallholder Scheme in Johor, Malaysia* (Doctoral dissertation, Universiti Putra Malaysia).

Gabdo, B. H., Abdlatif, I. B., Mohammed, Z. A., & Shamsuddin, M. N. (2014a). Comparative estimation of technical efficiency in livestock-oil palm integration in Johor, Malaysia: Evidence from full and partial frontier estimators. *Journal of Agricultural Science*, *6*(3), 140.

Gabdo, B. H., Abdlatif, I., Mohammed, Z. A., & Shamsuddin, M. N. (2014b). Homogenous smoothed dea-bootstrap optimization of robust technical efficiency in livestock-oilpalm integration in Johor, Malaysia. *Agricultural Journal*, *9*(1), 22-31.

Gebrezgabher, H. (2012). *Economic Efficiency of Groundnut Production: A Comparative Study of Local Seed Business Project Participant and Non-Participant Farmers in Babile District, Eastern Ethiopia* (Doctoral dissertation, Haramaya University).

Ghee-Thean, L., Ismail, M. M., & Harron, M. (2012). Measuring technical efficiency of Malaysian paddy farming: An application of stochastic production frontier approach. *Journal of Applied Sciences*, *12*(15), 1602.

Gocht, A., & Balcombe, K. (2006). Ranking efficiency units in DEA using bootstrapping an applied analysis for Slovenian farm data. *Agricultural Economics*, *35*(2), 223-229.

Greene, J. P. (1998). *A meta-analysis of the effectiveness of bilingual education*. Claremont, CA: Tomas Rivera Policy Institute.

Greene, W. (2001). *New developments in the estimation of stochastic frontier models with panel data* (No. 200106). Oviedo Efficiency Group.

Greene, W. H. (1980). Maximum likelihood estimation of econometric frontier functions. *Journal of econometrics*, *13*(1), 27-56.

Greene, W. H. (1990). A gamma-distributed stochastic frontier model. *Journal of econometrics*, *46*(1), 141-163.

Greene, W. H. (2003). *Econometric analysis*. Pearson Education India.

Gujarati, D. N. (2003). Basic Econometrics. 4th. *New York: McGraw-Hill*.

Guttormsen, A. G., & Roll, K. H. (2014). Production Risk in a Subsistence Agriculture. *The Journal of Agricultural Education and Extension*, *20*(1), 133-145.

Haider, M. Z., Ahmed, M. S., & Mallick, A. (2011). Technical efficiency of agricultural farms in Khulna, Bangladesh: Stochastic frontier approach. *International Journal of Economics and finance*, *3*(3), 248.

Haji, J. (2007). Production efficiency of smallholders' vegetable-dominated mixed farming system in eastern Ethiopia: A non-parametric approach. *Journal of African Economies*, *16*(1), 1-27.

Halkos, G., & Tzeremes, N. (2010). Performance evaluation using bootstrapping DEA techniques: Evidence from industry ratio analysis.

Haque, M. (2008). Sampling Methods in Social Research.

Hassan, S. (2004). *An analysis of technical efficiency of wheat farmers in the mixed farming system of the Punjab, Pakistan* (Doctoral dissertation, University of Agriculture, Faisalabad).

Henderson, B. B., & Kingwell, R. S. (2002, February). An Investigation of the Technical and Allocative Efficiency of Broadacre Farmers. In *Conference (46th), Canberra from Australian Agricultural and Resource Economics Society. Australia*.

Herrero, I. (2005). Different approaches to efficiency analysis. An application to the Spanish Trawl fleet operating in Moroccan waters. *European journal of operational research*, *167*(1), 257-271.

Hoang Linh, V. (2012). Efficiency of rice farming households in Vietnam. *International Journal of Development Issues*, *11*(1), 60-73.

Hokkanen, T. (2014). Estimating technical efficiency in Finnish industry: A stochastic frontier approach.

Hossain, M. K., Kamil, A. A., Baten, M. A., & Mustafa, A. (2012). Stochastic frontier approach and data envelopment analysis to total factor productivity and efficiency measurement of Bangladeshi rice. *PloS one*,*7*(10), e46081.

Hristovska, T., Watkins, K. B., Mazzanti, R., & Wilson Jr, C. E. (2013). Effects of Field Characteristics and Management on Technical, Allocative, and Economic Efficiency of Rice Production in Arkansas. In *Selected Paper (or Poster) prepared for presentation at the Southern Agricultural Economics Association SAEA) Annual Meeting,. University of Arkansas Rice Research & Extension Center, Stuttgart, Arkansas. Ed.*

Hussain, S. S. (1989). Analysis of Economic Efficiency in Northern Pakistan PhD Dissertation. *Univesity of IIIinois Champaign–Urban, IIIinois, USA*.

Huynh-Truong, H. (2009). Technical efficiency of rice producing households in the Mekong delta of Vietnam.

Idiong, I. C. (2007). Estimation of farm level technical efficiency in small scale swamp rice production in cross river state of Nigeria: a stochastic frontier approach. *World Journal of Agricultural Sciences*, *3*(5), 653-658.

Iliyasu, A., & Mohamed, Z. A. (2016). Evaluating contextual factors affecting the technical efficiency of freshwater pond culture systems in Peninsular Malaysia: A two-stage DEA approach. *Aquaculture Reports*, *3*, 12-17.

Iliyasu, A., Mohamed, Z. A., & Terano, R. (2016). Comparative analysis of technical efficiency for different production culture systems and species of freshwater aquaculture in Peninsular Malaysia. *Aquaculture Reports*, *3*, 51-57.

Illukpitiya, P. (2005). Technical efficiency in agriculture and dependency on forest resources: An economic analysis of rural households and the conservation of natural forests in Sri Lanka. *University of Hawaii*.

Ismail, A., & Mamat, M. N. (2002). The optimal age of oil palm replanting. *Oil Palm Industry Economic Journal*, *2*(1), 11-18.

Ismail, A., Simeh, M. A., & Noor, M. M. (2003). The production cost of oil palm fresh fruit bunches: the case of independent smallholders in Johor. *Oil Palm Industry Economic Journal*, *3*(1), 1-7.

Ismail, E. A. R. (April, 2015). A tobit regression approach based on DEA efficiency scores. *Global Journal of Engineering Science and Research Management,* 2(4)

Iwala, O. S., Okunlola, J. O., & Imoudu, P. B. (2006). Productivity and technical efficiency of oil palm production in Nigeria. *Journal of Food Agriculture and Environment*, *4*(3/4), 181.

Jaforullah, M., & Premachandra, E. (2003). Sensitivity of technical efficiency estimates to estimation approaches: An investigation using New Zealand dairy industry data.

Jondrow, J., Lovell, C. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of econometrics*, *19*(2-3), 233-238.

Kalirajan, K. P., & Shand, R. T. (1989). A generalized measure of technical efficiency. *Applied Economics*, *21*(1), 25-34.

Katharakis, G., Katharaki, M., & Katostaras, T. (2014). An empirical study of comparing DEA and SFA methods to measure hospital units' efficiency. *International Journal of Operational Research*, *21*(3), 341-364.

Khai, H. V., & Yabe, M. (2011). Technical efficiency analysis of rice production in Vietnam. *Journal of ISSAAS*, *17*(1), 135-146.

Kiatpathomchai, S. (2008). *Assessing economic and environmental efficiency of rice production systems in Southern Thailand: An application of data envelopment analysis* (Doctoral dissertation, Universitätsbibliothek Giessen).

Kirkley, J. E., Squires, D., Walden, J., & Ward, J. (1999, September). Assessing efficiency and capacity in fisheries. In *Prepared for the National Marine Service Workshop of ''Assessing Technical Efficiency and Capacity in Fisheries''. Silver Spring, MD, September*.

Kodde, D. A., & Palm, F. C. (1986). Wald criteria for jointly testing equality and inequality restrictions. *Econometrica: journal of the Econometric Society*, 1243-1248.

Koopmansa, T. C. (1951). An Analysis of Production as an Efficient Combination of Activities, Activity Analysis of Production and Allocation. *TC Koopmans. Ed.). Wiley. New York*.

Kopp, R. J., & Smith, V. K. (1980). Frontier production function estimates for steam electric generation: A comparative analysis. *Southern Economic Journal*, 1049-1059.

Kornai, J. (1986). The soft budget constraint. *Kyklos*, *39*(1), 3-30.

Krasachat, W. (2012). Organic production practices and technical inefficiency of durian farms in Thailand. *Procedia Economics and Finance*, *3*, 445-450.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and psychological measurement*, *30*(3), 607-610.

Krüger, J. J. (2012). A Monte Carlo study of old and new frontier methods for efficiency measurement. *European Journal of Operational Research*, *222*(1), 137-148.

Kumbhakar, S. C., & Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge university press.

Kuosmanen, T., & Kortelainen, M. (2005). Measuring eco-efficiency of production with data envelopment analysis. *Journal of Industrial Ecology*, *9*(4), 59-72.

Kyi, T., & von Oppen, M. (1999). Stochastic frontier production function and technical efficiency estimation: A case study on irrigated rice in Myanmar. *Sustainable Technology Development in Crop Production Session (Deutscher Tropentag, Berlin). Accessed from ftp. gwdg. de/pub/tropentag/proceedings/1999/referate/STD_C6. pdf on September*, *3*, 2013.

Laha, A., & Kuri, P. K. (2011). Measurement of allocative efficiency in agriculture and its determinants: Evidence from Rural West Bengal, India. *International Journal of Agricultural Research*, *6*(5).

Latruffe, L., & Nauges, C. (2013). Technical efficiency and conversion to organic farming: the case of France. *European Review of Agricultural Economics*, jbt024.

Latruffe, L., Balcombe, K., Davidova, S., & Zawalinska, K. (2005). Technical and scale efficiency of crop and livestock farms in Poland: does specialization matter?. *Agricultural economics*, *32*(3), 281-296.

Lee, J. S. H., Ghazoul, J., Obidzinski, K., & Koh, L. P. (2014). Oil palm smallholder yields and incomes constrained by harvesting practices and type of smallholder management in Indonesia. *Agronomy for Sustainable Development*, *34*(2), 501-513.

Leibenstein, H. (1966). Allocative efficiency vs." X-efficiency". *The American Economic Review*, *56*(3), 392-415.

Leleu, H. (2006). A linear programming framework for free disposal hull technologies and cost functions: Primal and dual models. *European Journal of Operational Research*, *168*(2), 340-344.

Lissitsa, A., Coelli, T., & Rao, D. P. (2005, August). Agricultural economics education in Ukrainian Agricultural Universities: An efficiency analysis using data envelopment analysis. In *Proceedings 11th International Congress of European Association of Agricultural Economists*.

Lovell, C. A. K. (1993). The Measurement of Productive Efficiency: Techniques and Applications Production Frontiers and Productive Efficiency.

Lovell, C. K., Travers, P., Richardson, S., & Wood, L. (1994). Resources and functioning: a new view of inequality in Australia. In *Models and measurement of welfare and inequality* (pp. 787-807). Springer Berlin Heidelberg.

Lowenberg, P. H. (1992). The marking of ethnicity in Malaysian English literature: Nativization and its functions. *World Englishes*, *11*(2-3), 251-258.

Mack, N., Woodsong, C., MacQueen, K. M., Guest, G., & Namey, E. (2005). Qualitative research methods: a data collectors field guide.

Maghyereh, A. I., & Awartani, B. (2012). Financial integration of GCC banking markets: a non-parametric bootstrap DEA estimation approach. *Research in International Business and Finance*, *26*(2), 181-195.

Malaysia Palm Oil Board (2015). Official Portal, Oil Palm Production Statistics http://www.mpob.gov.my, accessed 12/5/2016.

Malaysia Palm Oil Board (2016). Official Portal, Oil Palm Production Statistics http://www.mpob.gov.my, accessed 20/2/2016.

Malaysia Palm Oil Board (2016). Official Portal, Oil Palm Production Statistics http://www.mpob.gov.my, accessed 22/3/2017.

Malaysia. (2001). *Eighth Malaysia Plan, 2001-2005*. Economic Planning Unit, Prime Minister's Department.

Malaysian Business Online (2011). Malaysian Agricultural Sector, file///Malaysian Agricultural Sector_ Malaysian Business Online.htm.community.com.my, File Under: Agribusiness, 15th June, 2013.

Malaysian Economic Report (2011/2012). Gross Domestic Product GDP Growth Edge Communications Sdn BhD www.theedgemalaysia.com

Malaysian Palm Oil Board (MPOB) (2012). Malaysian Oil Palm Statistics, Ministry of Plantation Industries and Commodities, Malaysia.

Malaysian Palm Oil Board (MPOB) (2014). Malaysian Oil Palm Statistics 2013, 33rd edition. MPOB, Bangi

Malaysian Palm Oil Council (MPOC) (2014). Oils and fats focus: Malaysia industry update Retrieved from http://www.mpoc.org.my/Oils_and_Fats_Focus_-;_Malaysia_Industry_Update.aspx

Marshall, M. N. (1996). Sampling for qualitative research. *Family practice*, *13*(6), 522-526.

Masuku, M. B., Raufu, M. O., & Malinga, N. G. (2015). The Impact of Credit on Technical Efficiency among Vegetable Farmers in Swaziland. *Sustainable Agriculture Research*, *4*(1), 114.

McDonald, J. (2009). Using least squares and tobit in second stage DEA efficiency analyses. *European Journal of Operational Research*, *197*(2), 792-798.

Michael, S. (2012). MALAYSIA: stagnating palm oil yields impede growth. *USDA Foreign Agricultural Service*.

Minh, N. K., & Long, G. T. (2005). Efficiency of construction firms in Vietnam: assessment by parametric and non-parametric approach. *Munich Personal RePec Archive Paper*, (968), 44-59.

Molenaar, J. W., Persch-Orth, M., Lord, S., Taylor, C., & Harms, J. (2013). Diagnostic study on Indonesian Oil Palm Smallholders: developing a better understanding of their performance and potential. *International Finance Corporation, World Bank Group*.

Muhammad, I. J. (2009). *Efficiency analysis of cotton-wheat and rice-wheat systems in Punjab, Pakistan* (Doctoral dissertation, University of Agriculture, Faisalabad).

Mustapha, N. H. N. (2011). Technical efficiency for rubber smallholders under RISDA's supervisory system using stochastic frontier analysis. *Journal of Sustainability Science and Management*, *6*(1), 156-168.

Odeck, J. (2009). Statistical precision of DEA and Malmquist indices: a bootstrap application to Norwegian grain producers. *Omega*, *37*(5), 1007-1017.

Ofori-Bah, A., & Asafu-Adjaye, J. (2011). Scope economies and technical efficiency of cocoa agroforesty systems in Ghana. *Ecological Economics*, *70*(8), 1508-1518.

Ogundari, K., & Brümmer, B. (2011). Estimating Technical Efficiency, Input substitution and complementary effects using Output Distance Function: A study of Cassava production in Nigeria. *Agricultural Economics Review*, *12*(2), 62.

Ogundari, K., & Ojo, S. O. (2007). Economic efficiency of small scale food crop production in Nigeria: A Stochastic Frontier Approach. *Journal of Social Science*, *14*(2), 123-130.

Ogundele, F. O., & Okoruwa, V. O. (2004). Comparative analysis of technical efficiency between traditional and improved rice variety farmers in Nigeria. *African journal of economic policy*, *11*(1), 91-108.

Oil World (2014). Comparative Yields of Major Oil Seeds. Oil World Annual Report 2014. Retrieved from: http://www.oilworld.biz

Ojo, O. (2006). An examination of technical, economic and allocative efficiency of small farms: The case study of cassava farmers in Osun State of Nigeria. *Journal of Central European Agriculture*, *7*(3).

Okoye, B. C., Onyenweaku, C. E., & Agwu, A. E. (2008). Technical efficiency of small-holder cocoyam farmers in Anambra State Nigeria: Implications for agricultural extension policy. *Journal of Agricultural Extension*, *12*(1).

Okoye, B. C., Onyenweaku, C. E., & Asumugha, G. N. (2007). Economic efficiency of small-holder cocoyam farmers in Anambra state, Nigeria: A translog stochastic frontier cost function approach. *Agricultural Journal*, *2*(4), 535-541.

Olson, K., & Vu, L. (2009). Economic efficiency in farm households: trends, explanatory factors, and estimation methods. *Agricultural economics*, *40*(5), 587-599.

Onu, J. K., Amaza, P. S., & Okunmadewa, F. Y. (2000). Determinants of Agriculture and Social Research. *Journal of Economic Development*, *6*(1), 9-16.

Oppong, S. H. (2013). The problem of sampling in qualitative research. *Asian journal of management sciences and education*, *2*(2), 202-210.

Otero, L. D., Centeno, G., Otero, C. E., & Reeves, K. (2012). A DEA–Tobit Analysis to Understand the Role of Experience and Task Factors in the Efficiency of Software Engineers. *IEEE Transactions on Engineering Management*, *59*(3), 391-400.

Padilla-Fernandez, M. D., & Nuthall, P. L. (2009). Technical efficiency in the production of sugar cane in central Negros area, Philippines: An application of data envelopment analysis. *J. Int. Soc. Se. Asian. Agric. Sci*, *15*, 77-90.

Paul, C., Nehring, R., Banker, D., & Somwaru, A. (2004). Scale economies and efficiency in US agriculture: are traditional farms history?. *Journal of Productivity Analysis*, *22*(3), 185-205.

Petersen, N. C. (1990). Data envelopment analysis on a relaxed set of assumptions. *Management Science*, *36*(3), 305-314.

Pichler, M. (2013). "People, planet & profit": Consumer-oriented hegemony and power relations in palm oil and agrofuel certification. *The Journal of Environment & Development*, *22*(4), 370-390.

Pius, C. I., & Odjuvwuederhie, E. I. (2006). Determinants of yam production and economic efficiency among small-holder farmers in southeastern Nigeria. *Journal of Central European Agriculture*, *7*(2), 337-342.

Radam, A., Abu, M. L., & Abdullah, A. M. (2008). Technical efficiency of small and medium enterprise in Malaysia: A stochastic frontier production model. *International Journal of Economics and Management*, *2*(2), 395-408.

Rahman, A., Abdullah, R., Shariff, F. M., & Simeh, M. A. (2008). The Malaysian palm oil supply chain: the role of the independent smallholder. *Oil Palm Industry Economic Journal*, *8*(2), 17-27.

Rahman, K. M. M., Schmitz, P. M., & Wronka, T. C. (1999). Impact of Farm specific Factors on the Technical Inefficiency of Producing Rice in Bangladesh. *Bangladesh J. Agric. Econs*, *22*(2), 19-41.

Rahman, S. (2003). Profit efficiency among Bangladeshi rice farmers. *Food Policy*, *28*(5), 487-503.

Rahman, S., & Hasan, M. K. (2008). Impact of environmental production conditions on productivity and efficiency: A case study of wheat farmers in Bangladesh. *Journal of environmental management*, *88*(4), 1495-1504.

Reddy, A. R., & Sen, C. (2004). Technical inefficiency in rice production and its relationship with farm-specific socio-economic characteristics. *Indian Journal of Agricultural Economics*, *59*, 259-267.

Richmond, J. (1974). Estimating the efficiency of production. *International economic review*, 515-521.

Rizov, M., Pokrivcak, J., & Ciaian, P. (2013). CAP subsidies and productivity of the EU farms. *Journal of Agricultural Economics*, *64*(3), 537-557.

Rosli, A., Radam, A., & Rahim, K. A. (2013). Technical efficiency of pepper farms in Sarawak, Malaysia: an application of data envelopment analysis. *International Journal of Business and Social Science*, *4*(7).

Seyoum, E. T., Battese, G. E., & Fleming, E. M. (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa-Global 2000 project. *Agricultural economics*, *19*(3), 341-348

Sharma, K. R., Leung, P., & Zaleski, H. M. (1999). Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches. *Agricultural economics*, *20*(1), 23-35.

Simar, L., & Wilson, P. W. (1998). Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. *Management science*, *44*(1), 49-61.

Simar, L., & Wilson, P. W. (2000). A general methodology for bootstrapping in non-parametric frontier models. *Journal of applied statistics*, *27*(6), 779-802.

Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of econometrics*, *136*(1), 31-64.

Simar, L., & Wilson, P. W. (2011). Two-stage DEA: caveat emptor. *Journal of Productivity Analysis*, *36*(2), 205.

Singh, K., Dey, M. M., Rabbani, A. G., Sudhakaran, P. O., & Thapa, G. (2009). Technical efficiency of freshwater aquaculture and its determinants in Tripura, India. *Agricultural Economics Research Review*, *22*(2), 185-195.

Solís, D., Bravo-Ureta, B. E., & Quiroga, R. E. (2007). Soil conservation and technical efficiency among hillside farmers in Central America: a switching regression model. *Australian Journal of Agricultural and Resource Economics*, *51*(4), 491-510.

Song, M. L., Zhang, L. L., Liu, W., & Fisher, R. (2013). Bootstrap-DEA analysis of BRICS' energy efficiency based on small sample data. *Applied energy*, *112*, 1049-1055.

Sundram, K., Chenayah, S., Sasekumar, A., Aikanathan, S., & Basiron, Y. (2015). Sustainable Management of Oil Palm Plantation Industry and the Perception Implications. *Journal of Oil Palm, Environment and Health (JOPEH)*, *6*.

Tauchmann, H. (2011). Partial frontier efficiency analysis for stata. Discussion paper, 1-15.

Tauer, L. (1995). Age and farmer productivity. *Review of Agricultural Economics*, 63-69.

Tauer, L. W. (1984). Productivity of farmers at various ages. *North Central Journal of Agricultural Economics*, 81-87.

Tauer, L. W. (2001). Efficiency and competitiveness of the small New York dairy farm. *Journal of dairy science*, *84*(11), 2573-2576.

Taylor, T. G., Drummond, H. E., & Gomes, A. T. (1986). Agricultural credit programs and production efficiency: an analysis of traditional farming in Southeastern Minas Gerais, Brazil. *American Journal of Agricultural Economics*, *68*(1), 110-119.

Tchale, H. (2009). The efficiency of smallholder agriculture in Malawi. *African Journal of Agricultural and Resource Economics*, *3*(2), 101-121.

Teal, F., Zeitlin, A., & Maamah, H. (2006). Ghana Cocoa Farmers Survey 2004: Report to Ghana Cocoa Board. *CSAE-Oxford University*.

Teoh, C. H. (2010). *Key sustainability issues in the palm oil sector*. A discussion paper for multi-stakeholders consultations (Commissioned by the World Bank Group).

Thapa, G., & Gaiha, R. (2011). Smallholder farming in Asia and the Pacific: Challenges and opportunities. *IFAD con ference on New Directions for Smallholder Agri culture*, *24*, 25.

Tijani, B. A., Ala, A. L., Maikasuwa, M. A., & Ganawa, N. (2011). Economic Analysis of Beekeeping in Chibok Local Government Area of Borno State, Nigeria. *Nigerian Journal of Basic and Applied Sciences*, *19*(2).

Tipi, T., Yildiz, N., Nargeleçekenler, M., & Çetin, B. (2009). Measuring the technical efficiency and determinants of efficiency of rice (Oryza sativa) farms in Marmara region, Turkey. *New Zealand Journal of Crop and Horticultural Science*, *37*(2), 121-129.

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica: journal of the Econometric Society*, 24-36.

Trochim, W. M., & Donnelly, J. P. (2001). Research methods knowledge base.

Trujillo, J. C., & Iglesias, W. J. (2013). Measurement of the technical efficiency of small pineapple farmers in Santander, Colombia: a stochastic frontier approach. *Revista de Economia e Sociologia Rural*, *51*, s049-s062.

Tulkens, H. (2006). On FDH efficiency analysis: some methodological issues and applications to retail banking, courts and urban transit. In *Public goods, environmental externalities and fiscal competition* (pp. 311-342). Springer US.

Ueasin, N., Liao, S. Y., & Wongchai, A. (2015). The Technical Efficiency of Rice Husk Power Generation in Thailand: Comparing Data Envelopment Analysis and Stochastic Frontier Analysis. *Energy Procedia*, *75*, 2757-2763.

Unit, E. P. Malaysia. (2010). 10th Malaysia Plan 2011-2015. *Economic Planning Unit, Prime Minister Department. Kuala Lumpur: Percetakan Nasional Malaysia Berhad*.

United States Department of Agriculture (USDA) (2011). United States Department of Agriculture. Data and statistics, internet explorer. ww.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

United States Department of Agriculture (USDA) (2015). United States Department of Agriculture. Data and statistics, internet explorer. ww.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

Wadud, A., & White, B. (2000). Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods. *Applied economics*, *32*(13), 1665-1673.

Watkins, K. B., Hristovska, T., Mazzanti, R., Wilson Jr, C. E., & Watkins, B. (2013, January). Measuring Technical, Allocative, and Economic Efficiency of Rice Production in Arkansas using Data Envelopment Analysis. In *Annual Meeting, February* (pp. 2-5).

Wheelock, D. C., & Wilson, P. (2004). Trends in the efficiency of federal reserve check processing operations. *Review*, *86*.

Wheelock, D. C., & Wilson, P. W. (2003). *Robust nonparametric estimation of efficiency and technical change in US commercial banking* (No. 2003-037). Federal Reserve Bank of St. Louis.

Wilson, P. W., & Simar, L. (1995). *Bootstrap estimation for nonparametric efficiency estimates*. Center for Operations Research & Econometrics, Universite catholique de Louvain.

Wilson, P. W., & Wheelock, D. C. (2004, August). Robust nonparametric estimation of efficiency and technical change in US commercial banking. In *Econometric Society 2004 North American Summer Meetings* (No. 433). Econometric Society.

Winsten, C. B. (1957). Discussion on Mr. Farrell's paper. *Journal of the Royal Statistical Society*, *120*, 282-284.

Wissler, L. (2015). smallholder challenges in the growing palm oil industry. *The Pardee Papers*, (30).

Wooldridge, J. M. (2015). *Introductory econometrics: A modern approach*. Nelson Education.

World Bank Group (Ed.). (2016). *World Development Indicators 2016*. World Bank Publications.

Wossink, A., & Denaux, Z. S. (2006). Environmental and cost efficiency of pesticide use in transgenic and conventional cotton production. *Agricultural Systems*, *90*(1), 312-328.

Xu, X., & Jeffrey, S. R. (1998). Efficiency and technical progress in traditional and modern agriculture: evidence from rice production in China. *Agricultural economics*, *18*(2), 157-165.

Yamane, T. (1967). *Problems to Accompany Statistics: An Introduction Analysis*. Harper & Row.

Yang, W., Shi, J., Qiao, H., Shao, Y., & Wang, S. (2016). Regional technical efficiency of Chinese Iron and steel industry based on bootstrap network data envelopment analysis. *Socio-Economic Planning Sciences*.

Zhu, J. (2000). Multi-factor performance measure model with an application to Fortune 500 companies. *European journal of operational research*, *123*(1), 105-124.