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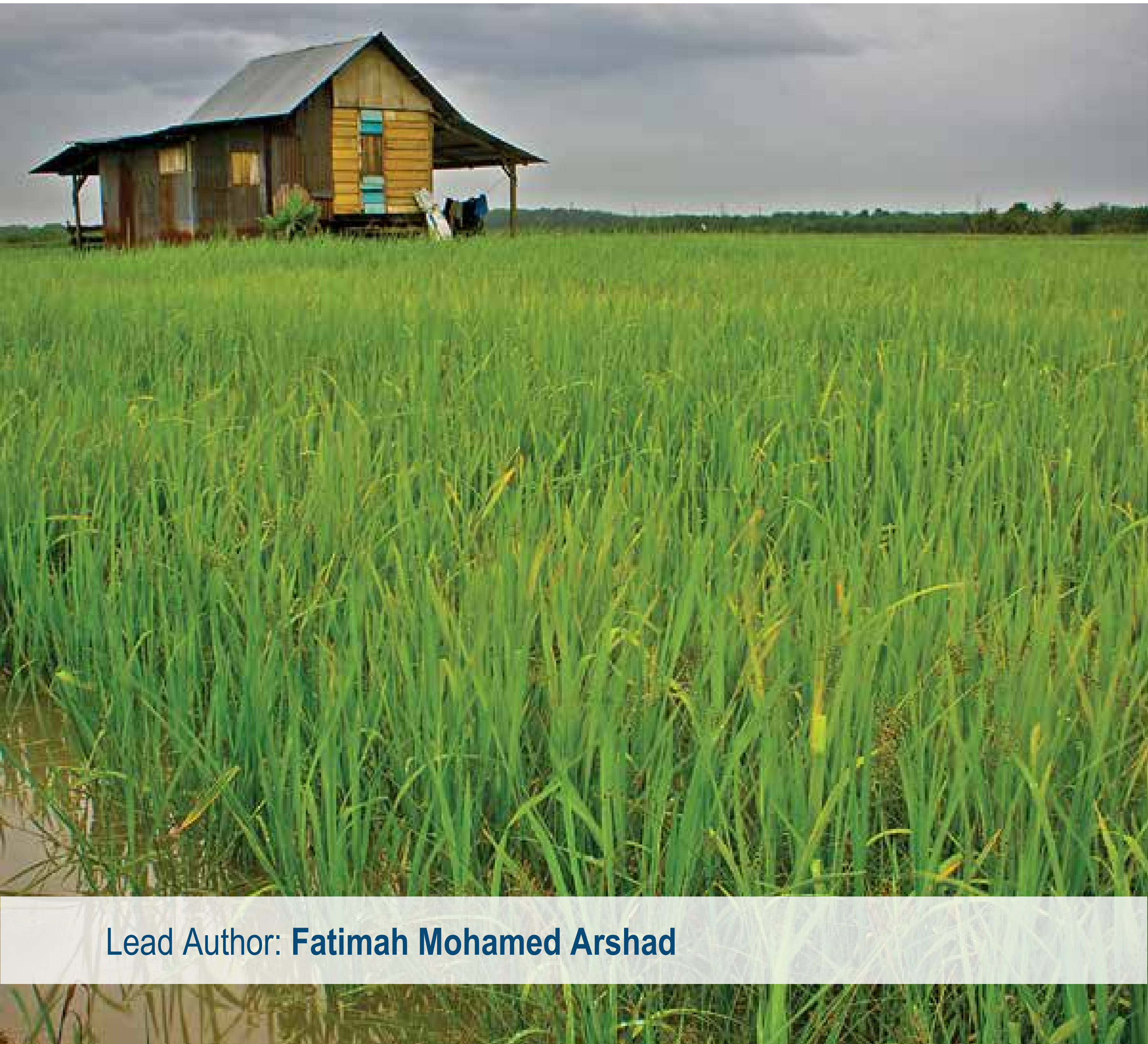
Implications of the Dominant Shift to Industrial Crops
in Malaysian Agriculture

PHASE I: SYSTEM DYNAMICS MODEL OF THE PADDY AND RICE SECTOR



Lead Author: **Fatimah Mohamed Arshad**

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Level 25, Mercu UEM
Jalan Stesen Sentral 5
Kuala Lumpur Sentral
50470 Kuala Lumpur, Malaysia

http://www.krinstitute.org/

Request for supplementary data may be sent to Illisriyani Ismail at illisriyani@gmail.com.

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Phase I: System Dynamics Model of the Paddy and Rice Sector

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Contents

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Contributors

Fatimah Mohamed Arshad (Datin Paduka, Prof., PhD), is a former visiting senior fellow at the Khazanah Research Institute and a research fellow at the Institut Kajian Dasar Pertanian dan Makanan, Universiti Putra Malaysia. Her area of expertise is in agricultural marketing and policy.

Bach Nguyen Luong (PhD) is an expert in system dynamics.

Kusairi Mohd Noh is a former associate professor at the Faculty of Economics and Management, Universiti Putra Malaysia and a senior research fellow at the Institut Kajian Dasar Pertanian dan Makanan, Universiti Putra Malaysia. His area of expertise is in natural resource economics and policy.

Illisriyani Ismail (PhD) is a research officer at the Institut Kajian Dasar Pertanian dan Makanan, Universiti Putra Malaysia. Her area of specialisation is in fisheries management and economics, and system dynamics.

Abdulla Ibragimov (PhD) is a postdoctoral researcher at the Institut Kajian Dasar Pertanian dan Makanan, Universiti Putra Malaysia. His area of expertise is in business management, agricultural and food policy, and system dynamics.

Gregory Ho Wai Son is a research associate at the Khazanah Research Institute. His field of interest is complexity economics, particularly in modelling the economy as a complex system comprising of many heterogeneous interacting agents.

Siti Aiysyah Tumin is a research associate at Khazanah Research Institute. Her research interests include labour economics and policies, migration, the informal economy, social capital formation and development economics.

Ahmad Ashraf Shaharudin is a research associate at Khazanah Research Institute. His main research interest lies in agricultural policy particularly those related to food security, sustainable resource management, and the application and adoption of technology in agriculture.

Abbreviations

ASEAN	**Association of Southeast Asian Nations**
AT	Adjustment time
ARoG	Average rate of annual growth
B40	
BAU	Business as Usual
BERNAS	Padi Beras Nasional Berhad
b	billion
CLD	**Causal Loop Diagram**
COBR%	Percentage change over base run
dmnl	**Dimensionless**
DOS	Department of Statistics Malaysia
DRC	Domestic Resource Cost
EP	**Expected Profitability**
EPU	Economic Planning Unit
ETP	Economic Transformation Plan
FAO	**Food and Agriculture Organization**
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FGD	Focus Group Discussion
GDP	**Gross Domestic Product**
GMP	Guaranteed Minimum Price
GR	Green Revolution
ha	**hectare**
IADA	**Integrated Agriculture Development Area**
ICT	Information and Communication Technology
IOT	Internet of Things
IRRI	International Rice Research Institute
KADA	**Kemubu Agricultural Development Authority**
KII	Key Informant Interview
LPN	**Lembaga Padi dan Beras Negara**
LPP	Lembaga Pertubuhan Peladang
MADA	**Muda Agricultural Development Authority**
MARDITECH	Marditech Corporation Sdn Bhd
MIER	Malaysian Institute of Economic Research
m	million
MOA	Ministry of Agriculture and Agrobased Industry
MSE	Mean Square Error

NAFAS	**National Farmers Organization**
NAFP	National Agro-Food Policy
NPK	Nitrogen, Phosphorus and Potassium
NL	Non-labour
NPC	Nominal Protection Coefficient
PCOB	**Percentage change over base year**
POBR	Policy over Base Ratio
R&D	Research and Development
RDE	Research and Development and Extension
RM	Ringgit Malaysia
RMSPE	Root Mean Square Percent Error
RM/t	Ringgit Malaysia per tonne
S&F	**Stock and Flow**
SD	System Dynamics
SSHP	Skim Subsidi Harga Padi or Paddy Price Subsidy Scheme
SSL	Self-sufficiency Level
t	**tonne**
t/ha	tonne per hectare
Y-L	**Yield - Labour Profile**
Y-NL	Yield - Non-labour Profile

PREFACE

The Malaysian agricultural crop mix has shifted from a high dependence on rubber in the 1970s – 1980s to oil palm beyond the 1990s. By 2015, the oil palm area occupied more than 70% of the agricultural land compared to rubber (14%), cocoa (2%) and food crops (10%). The growing shift to oil palm plantation in the early 1980s has reduced the other industrial crops area such as rubber and cocoa as well as some food crops. The predominance of oil palm as a single cropping enterprise entails economic and ecological risks. This phenomenon invites questions such as the source of conversion as well as the future risks and challenges faced by the industry. This study attempts to answer these questions by using a system dynamics methodology where a model is developed to explain the phenomenon and selected policy simulations are carried out to examine the impact of alternative policy interventions.

The study is divided into two phases. The first phase focused on research titled "System Dynamics Model of the Paddy and Rice Industry" which was carried out in August to December 2017. Phase II of the project (January – November 2018) examined the shift towards oil palm and its implications to the future of the sector.

This report provides the findings of the Phase I study. As for the paddy and rice industry, the major issue identified is the slow growth of productivity and hence production relative to consumption which is growing at a higher rate due to the increase in population. After the success of the Green Revolution (GR) in the late 1960s and 1970s, the sector has not shown a structural shift as experienced in other countries in the ASEAN region. Malaysia and other ASEAN countries started on the same footing under the Green Revolution drive, however, Malaysia's paddy yield lags behind other countries such as Vietnam and Indonesia.

Triggered by the rice crisis in the early 1970s, Malaysia has turned inward by insulating the industry from future shocks and other market vagaries through price control, market regulation, import monopoly through a parastatal body and the provision of input and output subsidies. The industry has remained under this regime for about five decades with slow improvement while Vietnam has liberalised their rice industry in the late 1980s with impressive results, outpacing Malaysia. The self-sufficiency level which reflects the availability of rice to the population has remained at about 70% since the late 1980s.

This study has applied system dynamics methodology to explain the slow growth of yield and production as well as low returns to farmers. This methodology was chosen as it is the most suitable approach to address complexities that exist in a system. These include: feedback relationship between variables, delays, non-linearities, path-dependence and trade-offs.

Based on published data and past literatures, the study identified four important sub-systems that affect the paddy production system. They are: rice requirement, R&D and Extension, farm inputs and farm revenue sub-systems. All the four sub-systems are interconnected to each other in a feedback loop. Within each of the subsystems, there are variables that are interrelated to each other in a circular causality loop. The study shows that a major driver of the paddy and rice system appears to be the rice requirement sub-system as the population grow faster than production. The requirement-production gap (or SSL) determines the government's allocation of subsidies to farmers and R&D allocation to ensure that the SSL targets are achieved.

The study was able to produce a system dynamics model for the paddy and rice sector and identify the structural relationships between variables and the resultant behaviour of the system. The model went through a validation test for robustness and later was used to examine the impact of a number of policy simulations on the system. The study has tested seven policy scenarios comprising various combinations of R&D and extension strategies, subsidy restructuring and development of local input sector.

The study shows that a full swing activation of R&D and extension (RDE) strategies are highly impactful to increase yield, production, self-sufficiency level and farmers' return even when input subsidy is withdrawn. A policy package that combines RDE and local input development yields the highest impact as it is able to address the two major challenges of paddy production: low yield and high cost of production.

In short, the vicious circle of slow growth of the paddy and rice sector is not unbreakable. Similarly the 40 year old subsidy is not indispensable. Energising the RDE sub-system and provision of adequate incentives for efficient use of input (variety, labour and non-labour input) hold the key towards the sustenance of the paddy and rice industry.

EXECUTIVE SUMMARY

1. Introduction

Institutional factors have shaped the structure and behaviour of the paddy and rice industry and hence impacted its performance. In view of its strategic importance for food security purpose, the industry is highly protected and insulated from external challenges. Some of the interventionist instruments implemented include; Guaranteed Minimum Price (GMP) (farm floor price), provision of input and output subsidies, and investment on R&D and extension (RDE), among others. Despite these interventions and large budgetary allocation to subsidies, the industry fails to indicate progressive growth in yield, self-sufficiency level (SSL) and improvement in the producers' income. Clearly, these institutional supports are in need of further examination and possible revisions. This poses as the motivation of the study.

This section provides a summary of this study. The discussion focuses on problem articulation, modelling process, findings, conclusions and policy recommendations.

2. Problem Articulation

A review of the performance of the paddy and rice sector suggests a number of pertinent behaviour that calls for explanation and alternative policy solutions. These are: first, the paddy yield showed a slow growth between 1980 – 2016 despite the large increment in the paddy subsidy allocation after the 2008 crisis. The allocation has tripled from an average of RM500m yearly before 2008 to an average of RM1.9b (2009 – 2016). The yield did not seem to respond well to the increase in the allocation as its average annual rate of growth (or ARoG) was estimated at 1.3% (2008 – 2016) which is lower than the ARoG for 1990 – 2008 estimated at 1.7%[1].

The ARoG of paddy yield for the period of 1980 – 2016 was 1.1%, the lowest compared to those achieved by Vietnam (3.1%), Philippines (1.7%), Indonesia (1.3%), China (1.3%) and Thailand (1.3%). Malaysia and these countries started on the same footing during the Green Revolution agenda in the 1960s but by 2016, Malaysia's yield was 41% lower than China, Vietnam (30%), and Indonesia (16%)[2].

Second, the low yield caused slow growth in production while consumption continues to increase due to the population growth. The ARoG for rice production was only 1% where it has increased from 1.3m t to 1.8m t for the period of 1980 – 2016. The planted area has reduced by an ARoG of 0.1% from 716,873 ha in 1980 to 688,770 ha in 2016. The rice requirement on the other hand has increased from 1.5m t to 2.5m t hence creating a gap which was met through import. The ARoG for rice requirement was about 1.8% while for import it was 7.6%.

1 MOA (2016)
2 IRRI (2018)

Third, despite the big increase in subsidies in the recent decade and extensive market interventions (import monopoly, price control, licencing and regulation), the return to farmers are still low where 90% of them belong to the B40 group[3]. Fatimah *et al.* (2019) estimated that the "net sustainable farm income[4]" of a farmer with yield 6 t/ha with a farm size of 2 ha is RM1,015 per month compared to RM539 per month for farm with yield 4 t.[5] Clearly, the net income of farmers are still below the B40 income line of RM3,000[6]. Low return can be explained by two major determinants, yield and production cost. While the yield is increasing very slowly, the cost of production continues to be high as most of the items are imported as the domestic input market is still underdeveloped.

3. Research Questions

The above deliberations invite the following questions:

(i) What are the structural and institutional factors and policy paradigms that cause the slow growth in paddy and rice production?

(ii) What are the structural and institutional factors that cause the low productivity and hence low return to paddy producer? and

(iii) What are the policy options needed to induce growth, equity and sustainability of the sector?

4. Objectives of the Study

The overall objective of the study is to identify structural transformation to induce inclusive growth and sustainability of the paddy and rice industry.

Specifically, the objectives are:

(i) To identify the structural and institutional factors and policy paradigms that cause the slow growth in production;

(ii) To examine the structural and institutional factors that cause the low productivity and hence low return to smallholders;

(iii) To develop a system dynamics model that captures the relationships among elements in the sector; and

(iv) To simulate alternative policy scenarios.

5. Modelling Process

5.1 System Dynamics Methodology

Systems thinking is a discipline that is concerned with an understanding of a system by examining the linkages and interactions between the components that comprise the

3 MOA (2019)
4 Net sustainable farm income is defined as net return to farm minus depreciation (McConnell and Dillion (1997))
5 Fatimah et al. (2019)
6 DOS (2016)

entirety of that defined system. One of the effective tools to understand a complex system is "system dynamics" which is capable of addressing complexities such as interdependency, mutual interaction, information feedback, delays, circular causality, trade-offs and identify unintended consequences.

The steps involved in the system dynamic methodology include;

(i) Problem articulation: To define the problem at hand and identify the study boundary

(ii) Dynamic hypotheses: Mapping the causal loop diagram based on initial hypothesis and develop stock and flow diagram

(iii) Formulation of the simulation model

(iv) Testing and validating the model

(v) Policy design and evaluation[7]

The study utilises both primary and secondary data for the modelling process. Secondary data refer to published reports, literature and statistics while primary data refer to findings from a number of focus group discussions (FGD) with farmers as well as key informant interviews (KII) in selected paddy areas. The study has carried out several FGDs and KIIs involving 41 farmers as well as 42 agricultural officers in eight selected paddy areas in Malaysia.

5.2 Dynamic Hypotheses

The dynamic hypotheses tested are:

(i) The institutional factors, particularly R&E and extension, are crucial in affecting the realised paddy yield through better extension, higher yield and cropping intensity;

(ii) Producers are more responsive to price incentive than input subsidies; and

(iii) Input sector development may help reduce the cost of paddy production and hence increase the producer's income.

5.3 Policy Design and Evaluation

The major institutional factors considered are:

(i) R&D and Extension (in the areas of yield improvement, extension and cropping intensity);

(ii) Subsidies and pricing intervention (Guaranteed Minimum Price [GMP]); and

(iii) Development of local input sector.

Based on the model developed, seven policy scenario runs were implemented. They are:

S1: Total transfer of input subsidy to output subsidy and RDE strategy to intensify extension services.

S2: Immediate withdrawal of the input subsidy and RDE strategy to improve yield.

7 Sterman (2000)

S3: Continuous increase of input subsidy.

S4: Combination of intensification of paddy extension services, enhancement of R&D capacity and related infrastructure to increase potential yield and cropping intensity.

S5: Combination of S4 and development of local input sector.

S6: Combination of S4 and S1 (total transfer of input subsidy to output subsidy).

S7: Combination of S4 and S2 (immediate withdrawal of the input subsidy).

The list of simulations in table format is represented in Table 1 below.

Table 1 List of Simulations

Simulation	Subsidy restructuring			RDE strategy			Development of Local Input Sector
	Total transfer of input subsidy to output	Immediate withdrawal of input subsidy:	Continuous increase in input subsidy	Reduction in delay time	Yield improvement	Enhancing cropping intensity	
S1	X			X			
S2		X			X		
S3			X				
S4				X	X	X	
S5				X	X	X	X
S6	X			X	X	X	
S7		X		X	X	X	

Source: Authors

All the policy changes are assumed to start in 2018 and run until 2050. Each policy simulation results are compared to the base run or Business as Usual (BAU) results to assess its relative effectiveness.

6. Findings, Conclusions and Policy Recommendations

6.1 Findings

Table 2 lists the key takeaways from each simulation. Five impact variables are chosen here namely: *Expected variable cost per ha per year, Net revenue per ha per year, Paddy yield realized per ha per crop, Total rice production per year and SSL*. The effect on the variables is measured in terms of the difference between its simulated and base run or Business as Usual (BAU) values in 2050 in terms of absolute figures and percentages.

Table 2 Summary of Simulation Results

Sim	Key takeaways

S1: Total transfer of input subsidy to output subsidy and RDE strategy to intensify extension services

a. Impacted variables experience marginal improvement over BAU run. Variable cost increases by one-tenth, net revenue by 2% and yield, production and SSL, each by 1%.

Variable	BAU 2050	S1 2050	% change
Expected variable cost per ha per year (RM/ha/year)	17,260	18,899	9.5
Net revenue per ha per year (RM/ha/year)	28,141	28,689	1.9
Paddy yield realized per ha per crop (t/ha/crop)	7.3	7.4	
Total rice production per year (t/year)	2.9	3.0	1.1
SSL (%)	81	82	

S2: Immediate withdrawal of the input subsidy and RDE strategy to improve yield

a. Variable cost increases by about one-tenth but compensated by an increase in yield by 8%.
b. Impacted variables experience reasonable improvement over BAU run. Net revenue improves by 7%, production and SSL increase by 8%.

Variable	BAU 2050	S2 2050	% change
Expected variable cost per ha per year (RM/ha/year)	17,260	19,313	11.9
Net revenue per ha per year (RM/ha/year)	28,141	29,965	6.5
Paddy yield realized per ha per crop (t/ha/crop)	7.3	8.0	
Total rice production per year (t/year)	2.9	3.2	8.4
SSL (%)	81	88	

S3: Continuous increase in input subsidy

The continuous increase in input subsidies lightens the variable cost burden by 16% and increases net revenue by one-tenth but fails to increase yield, production and SSL.

Variable	BAU 2050	S3 2050	% change
Expected variable cost per ha per year (RM/ha/year)	17,260	14,530	-15.8
Net revenue per ha per year (RM/ha/year)	28,141	30,871	9.7
Paddy yield realized per ha per crop (t/ha/crop)	7.3	7.3	
Total rice production per year (t/year)	2.9	2.9	0
SSL (%)	81	81	

S4: RDE strategies to improve extension, yield and cropping intensity

a. Enhancing the three RDE functions is highly impactful.
b. Delay time in extension is reduced, yield and cropping intensity (hence planted paddy area) are increased.
c. Planted area and yield increase by about one-tenth, net revenue improves by a quarter, production and SSL increase by one-fifth.

Variable	BAU 2050	S4 2050	% change
Expected variable cost per ha per year (RM/ha/year)	17,260	19,621	13.7
Paddy planted area (ha)	637,853	708,106	11
Net revenue per ha per year (RM/ha/year)	28,141	35,242	25.2
Paddy yield realized per ha per crop (t/ha/crop)	7.3	8.0	9.4
Total rice production per year (t/year)	2.9	3.5	21.4
SSL (%)	81	98	

S5: Combination of S4 and development of local input sector

a. (a) and (b) as in S4.
b. It yields the highest value to all impact variables; variable cost reduces by one-third and revenue increases by more than half.
c. Yield, production and SSL increases are similar as in S4
d. It addresses the two major issues: slow yield and high variable cost.

Variable	BAU 2050	S5 2050	% change
Expected variable cost per ha per year (RM/ha/year)	17,260	11,337	-34.3
Net revenue per ha per year (RM/ha/year)	28,141	43,526	54.7
Paddy yield realized per ha per crop (t/ha/crop)	7.3	8.0	9.4
Total rice production per year (t/year)	2.9	3.5	21.4
SSL (%)	81	98	

S6: Combination of S4 and S1 (total transfer of input subsidy to output subsidy)

a. (a) and (b) as in S4.
b. The transfer increases variable cost and net revenue by about a quarter.
c. RDE strategies improve yield, production and SSL as in S4.

Variable	BAU 2050	S6 2050	% change
Expected variable cost per ha per year (RM/ha/year)	17,260	21,440	24.2
Net revenue per ha per year (RM/ha/year)	28,141	35,228	25.2
Paddy yield realized per ha per crop (t/ha/crop)	7.3	8.0	9.4
Total rice production per year (t/year)	2.9	3.5	21.4
SSL (%)	81	98	

S7: Combination of S4 and S2 (immediate withdrawal of the input subsidy)

a. (a) and (b) as in S4.
b. Due to the above, subsidy withdrawal does not reduce net revenue, yield, production and SSL.
c. Input subsidy withdrawal increases variable costs by a quarter.
d. Net revenue increases by about one-fifth.
d. RDE strategies improve yield, production and SSL as in S4.

<table>
<tr><th>Variable</th><th>BAU 2050</th><th>S7 2050</th><th>% change</th></tr>
<tr><td>Expected variable cost per ha per year (RM/ha/year)</td><td>17,260</td><td>21,440</td><td>24.2</td></tr>
<tr><td>Net revenue per ha per year (RM/ha/year)</td><td>28,141</td><td>33,423</td><td>18.8</td></tr>
<tr><td>Paddy yield realized per ha per crop (t/ha/crop)</td><td>7.3</td><td>8.0</td><td>9.4</td></tr>
<tr><td>Total rice production per year (t/year)</td><td>2.9</td><td>3.5</td><td rowspan="2">21.4</td></tr>
<tr><td>SSL (%)</td><td>81</td><td>98</td></tr>
</table>

Source: Authors, from model

Table 3 Ranking of Policy Simulations

<table>
<tr><th rowspan="2">Variable</th><th colspan="7">Ranking of Simulation</th></tr>
<tr><th>1st</th><th>2nd</th><th>3rd</th><th>4th</th><th>5th</th><th>6th</th><th>7th</th></tr>
<tr><td>Expected revenue per ha per year (RM/ha/year)</td><td>S6</td><td>S4, S5, S7</td><td>S2</td><td>S1</td><td>S3</td><td>..</td><td>..</td></tr>
<tr><td>Expected profitability per ha per year (RM/ha/year)</td><td>S5</td><td>S3</td><td>S4</td><td>S6</td><td>S7</td><td>S2</td><td>S1</td></tr>
<tr><td>Expected variable cost per ha per year (RM/ha/year)</td><td>S5</td><td>S3</td><td>S1</td><td>S2</td><td>S4</td><td>S6, S7</td><td>..</td></tr>
<tr><td>Net revenue per ha per year (RM/ha/year)</td><td>S5</td><td>S4</td><td>S6</td><td>S7</td><td>S3</td><td>S2</td><td>S1</td></tr>
<tr><td>Paddy yield realised per ha per crop (t/ha/crop)</td><td>S4 - S7</td><td>S2</td><td>S1</td><td>S3</td><td>..</td><td>..</td><td>..</td></tr>
<tr><td>Total rice production per year (t/year)</td><td>S4 - S7</td><td>S2</td><td>S1</td><td>S3</td><td>..</td><td>..</td><td>..</td></tr>
<tr><td>SSL (%)</td><td>S4 - S7</td><td>S2</td><td>S1</td><td>S3</td><td>..</td><td>..</td><td>..</td></tr>
</table>

Source: Authors, from model

In terms of ranking, it is clear that S5 is the most effective policy mix as it ranked the first for six impact variables (Table 3). S5 gives the highest value for six impact variables namely: expected profitability, net revenue, yield, rice production and SSL and the lowest variable cost. S6 provides the highest value for four impact variables; namely expected revenue, yield, rice production and SSL. S4 – S7 ranked first for yield, rice production and SSL. S3 ranked the lowest for expected revenue, yield, rice production and SSL. In short, the most effective strategies are the mixes of RDE and local input sector development (S5) and transfer of input to output (S6). The least effective strategy is S3 (continuous increase in input subsidy).

6.2 Conclusions

The lacklustre yield growth and low net revenue to farmers are the results of an eco-system where the R&D and extension sub-system is not fully energised to bring maximum impact on important variables such as farmer revenue, yield, production and SSL. The poor performance of S1 to S3 supports this statement. The failure of S1 to S3 in bringing out significant impact is due to the strong dominance of the other RDE loops not taken into account in the simulation particularly R&D and crop intensity loop. Without the full complementation of the RDE strategies, subsidy restructuring alone or weak combination of RDE strategies and the latter, will not create significant improvement to the system.

The full activation of RDE functions in expediting extension service, improving yield and cropping intensity combined with either subsidy restructuring or input sector development (S4 – S7) bring significant improvement to the whole system. As shown in the ranking table, S4 – S7 give the most impact on yield, production, SSL and farmer revenue.

The combination of RDE strategies and development of local input sector (S5) gives the highest return as it addresses fully the two major challenges in paddy production ie., low yield and high variable cost. This simulation results in lowest reduction in variable cost, highest revenue, paddy yield, rice production, and SSL.

A single policy of continuous increase in input subsidy (S3) and a weak combination of RDE strategy and subsidy restructuring (S1 and S2) are ineffective in impact. This is proven in the poor performance of S1 to S3 which fail to bring significant improvement on yield, production and SSL.

The 40-year old input subsidy is not indispensable. Even when input subsidy is totally withdrawn immediately or transferred to output, complementation with a full functioning of RDE (S6 – S7) is effective enough to energize the whole system towards higher yield, production, SSL and farmer revenue. These simulations prove that the 40-year old input subsidy is dispensable on condition that RDE is fully activated.

In short, the vicious circle of slow growth of the paddy and rice sector is not unbreakable, a new virtuous circle can be created. The simulations prove that subsidy is not the panacea to growth and sustainability. Based on the findings, the proposed eco-system of the new virtuous circle comprises an optimum complementarity of RDE strategies, productive subsidies and incentive and local input development. These entail: energising the RDE sub-system to enhance yield, cropping intensity and extension effectiveness, provision of productive incentives for efficient use of input (land, labour, non-labour input and capital) and actualise local input production to ensure the sustenance of the paddy and rice sector.

6.3 Policy Recommendations

The study proposes a virtuous cycle to break the current vicious circle of slow growth of productivity, production of paddy and rice and low return to paddy producers. The following are proposals based on the findings of the study.

(i) Institutional supports:

1. Reduce the gap between potential and realised yield through effective extension services and participatory research involving researcher, farmer and extension agent.
2. Intensify R&D for high yielding varieties.
3. Expedite R&D to increase cropping intensity.

(ii) Subsidies and incentives

Rationalization of subsidies with emphasis of output-based and productive subsidies and incentives with full supports from the R&D and extension services. Productive subsidies and incentives include those that encourage production efficiency or farm innovations (machines, gadgets, paddy-based products such as fertiliser and other value added products).

(iii) Input sector development

Development of local input sector; organic fertiliser, pesticides, small machines for small farms and ICT and IOT applications.

(iv) Systems thinking-based policy

Policy strategies must take into account the eco-system of the industry and the behaviour of its elements and market participants (producer, traders, millers and consumers).

(v) Evidence-based decision making

Modelling guides policy makers to understand relationships between elements in the system, behaviour, and performance. Policy modelling is needed to guide the policy makers and implementers in identifying the optimal strategies, their impact, trade-offs and long-term implications.

1

INTRODUCTION

1.1 Overview of the Paddy and Rice Industry

A snapshot of the history of Malaysia's paddy and rice industry is depicted in Appendix 1. The table summarises in figures the structural changes in the industry during the last 45 years in terms of area, production, yield, consumption, imports, and SSL and so on. The discussion in this section draws largely from this table.

The paddy and rice industry secures a unique place in the Malaysian economy as rice is a staple food for a large proportion of the population; hence it holds the pillar of the food security situation of the country. As proven in the 1972 and 2008 rice crises, the price hikes have caused social and political instabilities in certain parts of the world including Malaysia. This indicates the multi-roles of the rice as an economic, social and political commodity. For these reasons, the industry is subjected to a number of policy interventions, developmental as well as protective measures to safeguard the food security requirement.

The economic contribution of the sector to the country's Gross Domestic Product (GDP) is relatively small. For instance, the sector accounted for about 0.7% of the GDP in 1980, declined to 0.5% in 1990 and reached only 0.002% in 2015[8]. Similarly, its share of the agricultural GDP declined from 4.7% in 1980 to 0.2% in 2015. The number of establishments recorded in 2015 were 181 with a gross output worth RM196m. The number of paddy farmers have declined from 208,000 in 1985[9] to 197,000 in 2015[10]. Paddy farms are mainly smallholders with an average size recorded at 1.2 hectares (ha) in 1970[11] and to 2 ha in 2016[12]. After the Green Revolution[13] and purposive development support, the incidence of poverty has been reduced from 88.1% in 1970 to 48.3% in 1990 and by 2015 the number of absolute poverty[14] is significantly small. However, paddy farmers are still the highest in relative poverty compared to other agricultural

8 DOS (2016)
9 MOA (2011)
10 MOA (2016)
11 Selvadurai (1978)
12 MOA (2016)
13 Green Revolution refers to the incorporation of scientific advances in plant breeding with technological packages that have allowed the yield potential of the crops to be realized more fully and under conditions experienced by farmers from developing countries. The Green Revolution was initiated in the 1960s in developing countries in Asia including Malaysia (FAO (1996))
14 As of October 2015, the new global line was updated to USD1.90/day

sectors[15]. Paddy area accounted for about 20.5% of the agricultural land in 1970, 12.4% in 1990 and 9.9% in 2015. There are twelve designated "granary areas" that specialises in paddy production which accounted for 60.4% of the total paddy area in 2015[16]. In 1980, the share of the granary area was about 44% of the total paddy area.

The behaviour and performance of the industry is largely shaped by the policy that governed the industry. The policy thrusts of this sector were focussed on food security which were translated into three objectives:

(i) to maintain high price of paddy and hence income to the farmers;

(ii) to achieve a certain level of SSL; and

(iii) to ensure stable and high quality supply of rice to consumers[17].

The policy has been modified over time, but these fundamental thrusts remained. The new National Agrofood Policy (2011 – 2020) focusses on the need to ensure food security by enhancing availability, accessibility, and utility of food (including rice), improve competitiveness and development of agro-preneurs. However, these thrusts are not totally reflected in the paddy and rice industry. For instance, the current rice policy is heavily centric towards "availability" function through supports and investment to increase rice production. Similarly, "to improve competitiveness" for the rice industry is irrelevant as it is highly protected and insulated from the world market. The nominal protection coefficient (NPC)[18] of paddy and rice sector has increased from 1.09 in 1979[19] to 2.39 in 1985[20]. Similarly, the domestic resource cost[21] has increased from 0.39 in 1979[22] to 0.86 in 2008[23]. Amin *et al*. (2010) estimated that the NPC for output was 1.89 and NPC for input was 1.13 in 2008. In 2015, the NPC for rice was estimated at 1.38[24]. Despite the improvements in the world market such as higher exportable surplus, better information flow, a relatively stable rice supply[25], Malaysia has not revised its protective policy stance. In fact, after 2008, the country decided to intervene deeper through higher subsidies, continuation of price control and maintain BERNAS as a sole importer of rice to manage stockpile, ensure a stable price to consumer, to function as the buyer of last resort and other related social functions. These are reflected in the National Food Security Policy, 2008[26]. The National Agrofood Policy (2011 – 2020) or NAFP however listed a

15 MARDITECH (2003)
16 MOA (2016)
17 EPU (1975)
18 NPC refers to ratio of the domestic price observed in the presence of the policy in question, and a reference price observed elsewhere. The relevance of the NPC depends on the potential for competitive arbitrage to enforce the law of one price in the absence of policy, so the measure is useful only to the extent that the reference price includes all relevant transaction costs across space, time and product quality (Master (2003)).
19 Fatimah (1995)
20 Tan Siew Huey (1987)
21 Domestic Resource Cost (DRC) ratio is defined as the shadow value of nontradable factor inputs used in an activity per unit of tradable value added (Master and Winter-Nelsen, 1995).
22 Tan Siew Huey (1987)
23 Amin et al. (2010)
24 Authors' calculation.
25 Rashid et al. (2008)
26 MOA (2008)

number of developmental policy objectives to increase productivity, mechanisation, use of by-products, restructuring paddy subsidies and strengthening farmers' institutions[27].

Currently the role of paddy and rice development is entrusted to the Ministry of Agriculture and Agro-based Industry. Hence it is no surprise that the rice policy tends to focus more on "availability" rather than "accessibility" and "utility or nutrition security" of the food security dimensions. This is because the latter two pillars of food security are a function of other macro-economic variables such as increase in income, lifestyle, education and other factors which are beyond the function of the said Ministry of Agriculture, then and now. The focus on "availability" through production increase was particularly strong after independence as the country began its journey towards development. Malaysia had embarked on the Green Revolution of the 1960s and 1970s with the help of World Bank with impressive results. The Green Revolution was largely responsible in expanding the paddy area, production and yield as well as reducing the poverty problem in this sector[28]. The paddy area has increased by 2.7% from 704,700 ha in 1970 to 716,800 ha in 1980. The paddy area, however, varied between years largely due to climatic factors and reached 730,000 ha in 2015[29]. The other strategies have been developmental particularly provision of good drainage and irrigation facilities, roads and other basic infrastructures. As shown in Appendix Table A1, in 1970, the share of irrigation development expenditure accounted for 31% of the agricultural development expenditure and reduced to 28% in the year 2000. These investments were proven beneficial as poverty diminishes, while yield and production increase to some extent.

As for farm institution, the focus was on the development of farmers associations and cooperatives. As of 2016, there were 276 Farmers Associations with 778,812 members[30]. Agrobank was established in 1969 to help farmers with micro-credit facilities. However, it is the subsidies and cash incentives that are taking a big toll on the government's coffer as the total subsidies have increased four-folds between 1990 and 2015[31]. The list of subsidy allocation provided by the government between 2012 – 2016 is shown in Table 1.1.

27 MOA (2011)
28 Ahmad (2010)
29 Alam et al. (2019)
30 LPP (2017)
31 MOA (2016)

Table 1.1 Subsidy Allocation (RM m), 2012 – 2016

Subsidy/Incentive	2012	2013	2014	2015	2016
Certified Paddy Seed Incentive *Insentif Benih Padi Sah (IBPS)*	85	85	85	85	50
Paddy Production Incentive *Insentif Pengeluaran Padi (IPP)*	150	563	563	563	500
Food Security Policy *Dasar Jaminan Bekalan Makanan (DJBM)*	413	-	-	-	-
Paddy Price Subsidy Scheme *Skim Subsidi Harga Padi (SSHP)*	480	480	480	480	616
Paddy Production Input Incentive *Insentif Input Pengeluaran Padi (IIPP)*					112
Incentive for Improvement in Yield *Insentif Peningkatan Hasil (IPH)*	80	80	80	20	-
Federal Government Fertiliser Scheme *Skim Baja Padi Kerajaan Persekutuan (SBPKP)*	409	465	465	465	400
Price Rice Subsidy *Subsidi Harga Beras (ST15%)*	488	528	528	528	-
Fertiliser Subsidy and Pesticide for Hill Rice *Subsidi Baja dan Racun Padi Bukit/Huma (SBRPB)*	-	-	-	70	70
Total	**2,105**	**2,201**	**2,201**	**2,211**	**1,748**

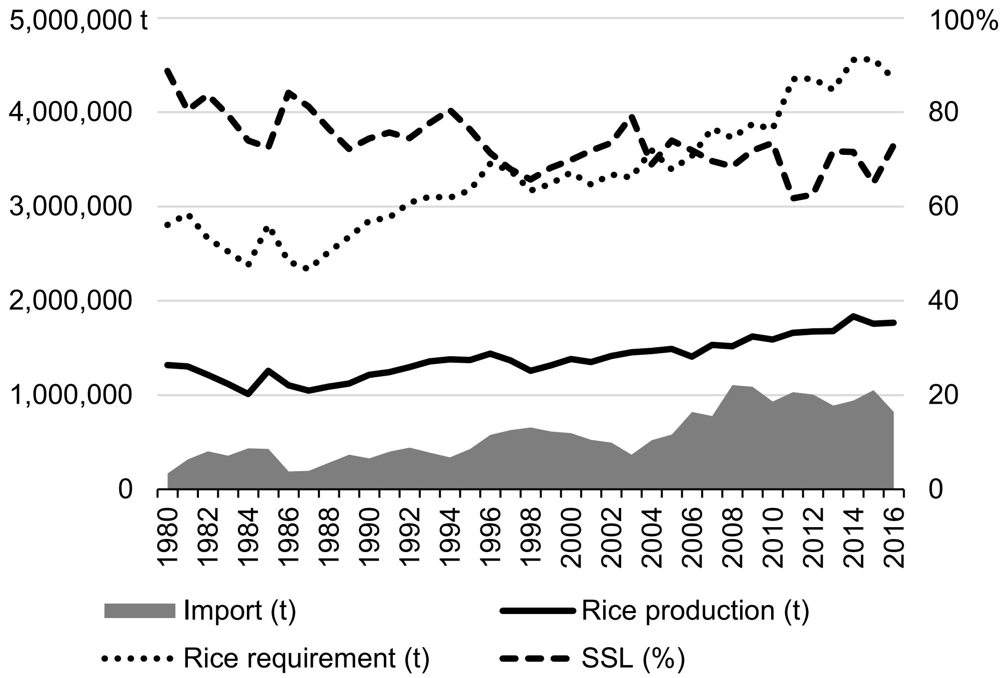
Source: MOA (2016)

1.2 Sector Performance

The impact of the combinations of all the above policies on the industry can be measured by looking at major performance indicators such as SSL, yield and farmers income. As for SSL, it is calculated as a ratio of production to domestic consumption. The level of SSL achieved was more or less around the target of 75% in 1970, and increased to a record high at 92% in 1980 (which exceeded the target of 90%). However, between the periods of 1980 to 1994, the average realised SSL was reduced to 78% which reduced further to 70% for the periods of 1995 – 2016.

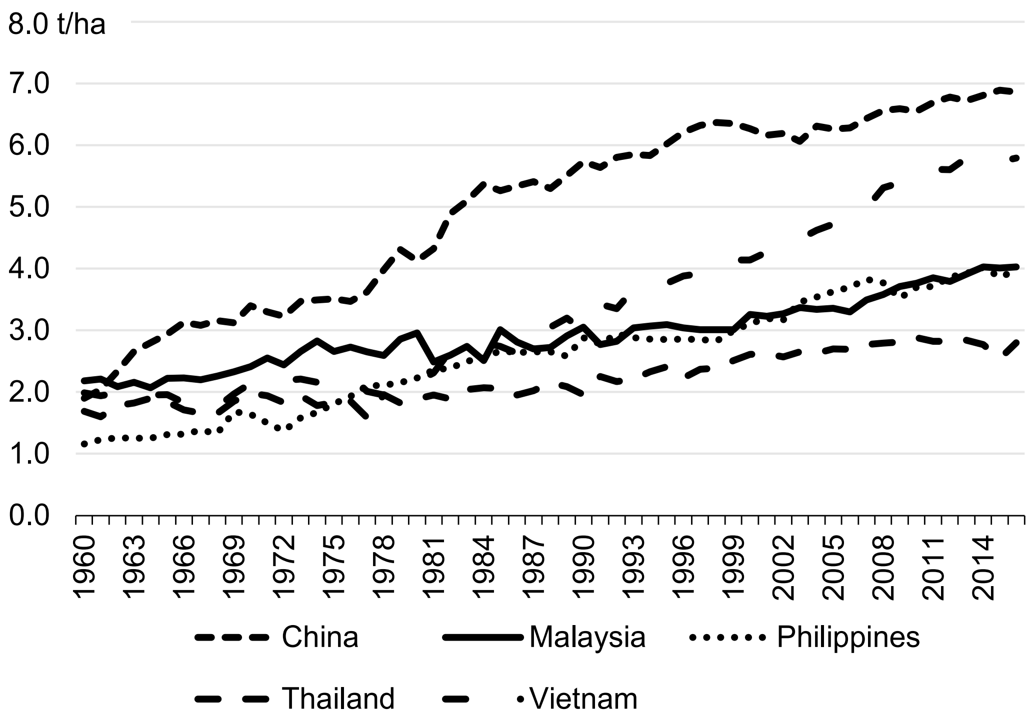
The ARoG for rice production is only 1% where it has increased from 1.3m t to 1.8m t for the period of 1980 – 2016 (Figure 1.1). The planted area has reduced by an ARoG of 0.1% from 716,873 ha in 1980 to 688,770 ha in 2016. The rice requirement on the other hand has increased from 1.5m t to 2.5m t during the said period hence creating a gap which was met through import. The ARoG for rice requirement is about 1.8% while for import it is 7.6%.

Figure 1.1 Production, Consumption and Import of Rice (t) and SSL (%), 1980 – 2016



Source: Time Series: Paddy, DOS (2017a), MOA (2017) (for SSL data), and FAOSTAT (2017a) (for trade data).

Figure 1.2 Paddy Yield of Selected Countries (t/ha), 1960 – 2016

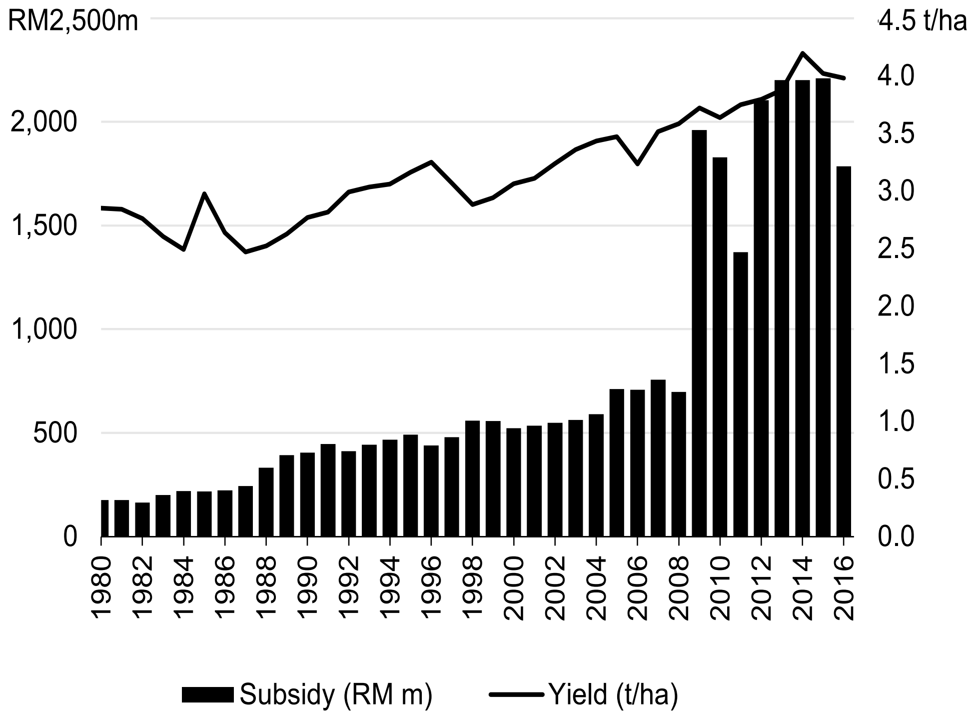


Source: Yield-Paddy, International Rice Research Institute (IRRI) (2017)

One of the important parameters that determine production is yield. Analysing yield trend indicates that it is increasing at a slow pace over time. For instance, the yearly annual rate of growth between 1960 – 1980 (i.e. during the Green Revolution era), was estimated at 1.8% which later decreased to 1.1% for the years between 1980 – 2015. In 2016, Malaysia's yield was about half of the yield in China (6.9 t/ha) and 28% lower than that of Vietnam (5.7 t/ha). Clearly, despite the same starting point of Green Revolution adoption, Malaysia's paddy yield lags behind compared to other countries (Figure 1.2).

As shown in Figure 1.3, the allocation of subsidies has increased three-fold from the average of RM500m before 2008 to RM1.8b in 2016[32]. The accumulated value of subsidies from 1980 to 2016 was RM28bn. About more than half of the accumulated subsidy allocation was spent between 2009 – 2016. Nevertheless, paddy yield managed to grow at 1.4% per year during the said period.

Figure 1.3 Paddy Yield (t/ha) and Allocation of Subsidies (Input and Output) (RM m), 1980 – 2016



Source: MOA (2016)

The income to the producers is protected by the GMP mechanism which is set above the world market price. The GMP level has been revised from RM650/t in 2006 to RM750/t in 2008 and later RM1,200/t in 2012[33]. During this period a Paddy Price Subsidy Scheme or *Skim Subsidi Harga Padi* (SSHP) was introduced at RM33/t which later increased to RM165/t (1980), RM248/t (1990) and RM300/t in 2012. This scheme is basically an income transfer in the form of cash given to the farmers based on the output sold.

The evidence are indicating that despite the increase in GMP and cash subsidy, the farmers received low returns relative to other agricultural ventures. A World Bank study in 1988 estimated that the average monthly income of a high yielding (4 t/ha) paddy farmer was

32 MOA (2016)
33 Ibid.

about RM272/ha compared to RM155/ha for a low yielding (2.1 t/ha) farmer[34]. The share of subsidies of the production cost was 48%. In 2007, it is estimated that the average paddy farmers' income in the granary areas was RM2,087/ha which gave a monthly net income of RM694 for a 2 ha farm with a yield of 4 t/ha[35]. Fatimah *et al.* (2019) estimated that the "net sustainable farm income"[36] of a farmer with yield 6 t/ha with a farm size of 2 ha is RM1,015/month compared to RM539/month for farm with a yield of 4 t/ha[37]. Clearly, the net income of farmers from paddy are still below the B40 income line of RM3,000[38].

Amin *et al.* (2010) estimated that the withdrawal of the cash paddy price subsidy will reduce the net income by 98%, compared to 23% if the input subsidy is withdrawn, indicating the significant role of SSHP relative to input subsidy[39]. Similarly Fatimah *et al.* (2019) indicated that the withdrawal of input subsidy (while output subsidy is maintained) will reduce the farmers net sustainable farm income by 40% for farmers with 8 t/ha, 62% for farmers with 6 t/ha and negative figure for those less than 4 t/ha[40]. These findings indicate that there is little improvement in farmers' income over the years and input subsidies are their farming lifeline.

The above deliberations indicate that the paddy and rice industry in Malaysia has not shown rapid improvement in terms of SSL, farmers' income and yield despite the large infrastructural investment and wide range of market interventions implemented from input to consumer plate. The industry structure in general has not shown much improvement whereby the farmers remain relatively poor, the post farm market structure is becoming non-competitive with higher concentration among large millers and the recent joint-venture programme between BERNAS with wholesaler and millers merely strengthen their procurement activities and power[41].

World Bank in 1988 has summarised the paddy and rice sector in Malaysia as neither "viable" nor "sustainable" as the market interventions have many unintended effects that added to industry costs requiring further subsidies[42]. Later studies also derived at a similar conclusion in that the protection strategies resulted in a number of market inefficiencies and high fiscal burden to the government[43]. Without a structural change, the industry will continue to be trapped in the current situation. A change is needed to prompt growth again as proven by the Green Revolution's success. This entails improvements in crop yield and cropping intensity as well as providing a more competitive input and rice market[44]. As concluded by Sharma and Gulati (2015), China's success in agricultural production is largely driven by improvements in crop yield and productivity besides institutional reforms, technological change, and enabling investment in agricultural R&D[45]. Similarly, the varietal

34 The World Bank (1988)
35 Amin et al. (2010)
36 Net sustainable farm income is defined as net return to farm minus depreciation (McConnell and Dillion (1997)).
37 Fatimah et al. (2019)
38 DOS (2016)
39 Amin et al. (2010)
40 Fatimah et al. (2019)
41 MIER (2010)
42 The World Bank (1988)
43 See also Tan Siew Huey (1987), MARDITECH (2003), MIER (2010), Amin et al. (2010)
44 MIER (2010)
45 Sharma and Gulati (2015)

improvement was largely responsible for bringing a big change in rice production in Vietnam[46]. The national agricultural research systems have also played a critically important role in developing location-specific and appropriate technologies. Otsuka and Kalirajan (2006) believe that a similar strategy would bring big potential improvements to cereals in Africa[47]. Numerous authors have acknowledged the role of productivity improvement in reducing poverty and elevating food security[48]. In Malaysia too, yield improvement is deemed necessary to jumpstart future production increase[49]. Raziah *et al.* (2010) emphasised the need to produce highly resistant varieties to address climate change issues and improve productivity[50]. Besides variety, institutional and policy reforms, technological change, and enabling investment in agricultural research and development play important roles[51]. Based on these evidence, this study attempts to explain the slow growth in yield, production and unchanged SSL levels and seek alternative policy considerations.

The report is organised as follows. The following section discusses the paddy modelling process. This is followed by deliberations on the model-based policy simulations. The conclusions and recommendations are provided in the last section of the report.

46 Thi and Kjisa (2006)
47 Otsuka and Kalirajan (2006)
48 Hayami and Kikuchi (1982), Barker and Herdt (1985), David and Otsuka (1994), Pingali, Hossain, and Gerpacio (1997).
49 Najim et al. (2007), Bala et al. (2014), Siwar et al. (2014) and Ismail & Ngadiman (2017).
50 Raziah et al. (2010)
51 Fao U (2009)

2

MODELLING PROCESS

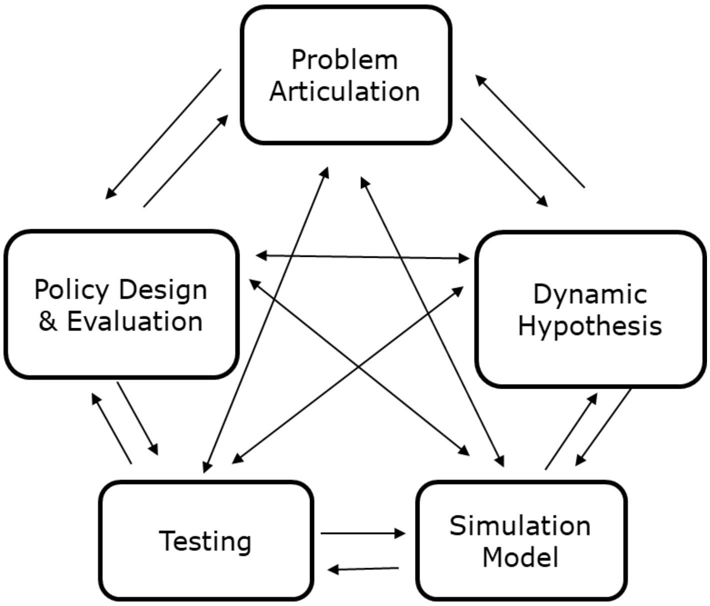
According to the founder of system dynamics[52], this methodology is an effective and useful method to analyse complex systems by integrating the subsystems and parts into a whole, which can then be simulated to develop insights into its dynamic behaviour. He further concluded that the method provides a dynamic framework to give meaning to detailed facts, source of information, and human response. Based on these premises, Sterman (2001) defined system dynamics as a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems[53]. It is a rigorous modelling method that enables one to build formal computer simulations of complex systems and use them to design more effective policies and organizations.

All simulation models have their own strength and weaknesses. A number of studies have compared this method against the conventional ones such as econometrics, input output model, optimisation and computable general[54]. Andrea indicated the strengths of SD are in the problem identification, policy formulation, assessment, monitoring and evaluation, complementarity between different disciplines and inclusiveness (involvement of stakeholders in the modelling). Techniques like econometrics are entirely based on historical trends and lack feedbacks and does not capture possible emerging dynamics. As for optimisation method; it supports the estimation of targets, understanding the key limits of the system. However, its weaknesses are, it only provides an "end" with little insights on the "means" hence it is not viable for highly dynamic and cross sectional systems. On the other hand, SD focuses on structures to drive behaviour; horizontal sectoral representation; knowledge integrator ie advantages that are not provided by other methodologies. Andrea (2013), for instance, indicated that to study a Green Economy, SD method can endogenously represent economic, human and natural capital[55].

Figure 2.1 presents the process in building a system dynamics model. As shown, the modelling process is a feedback process, not a linear one. The model built goes through constant iteration, continual questioning, testing, validating and refinement. The modelling process starts with the problem articulation and identifying the boundary of the problem. This is followed by proposing the dynamic hypothesis, model simulation, testing and policy design and evaluation. Iteration can occur from any step to any other step.

52 Forrester (1992)
53 Sterman (2001)
54 Meadows (1980), Meadows and Robinson (1985), Andrea (2013) and Bockermann et al. (2015)
55 Andrea (2013)

Figure 2.1 The Process in Building a System Dynamics Model



Source: Sterman (2000)

The details of the steps in system dynamics modelling are shown in Table 2.1 while further discussion on this methodology in provided in Appendix 2.

Table 2.1 Steps of the Modelling Process

1. Problem Articulation (Boundary Selection)
   - **Theme selection:** What is the problem? Why is it a problem?
   - **Key variables:** What are the key variables and concepts we must consider?
   - **Time horizon:** How far in the future should we consider? How far back in the past lie the roots of the problem?
   - **Dynamic problem definition (reference modes):** What is the historical behaviour of the key concepts and variables? What might their behaviour be in the future?
2. Formulation of Dynamic Hypothesis
   - **Initial hypothesis generation:** What are the current theories of the behaviour?
   - **Endogenous focus:** Formulate a dynamic hypothesis that explains the dynamics as endogenous consequences of the feedback structure.
   - **Mapping:** Develop maps of causal structure based on initial hypotheses, key variables, reference modes, and other available data, using tools such as:
     - ◊ Model boundary diagrams,
     - ◊ Subsystem diagrams,
     - ◊ Causal loop diagrams,
     - ◊ Stock and flow maps,
     - ◊ Policy structure diagrams,
     - ◊ Other facilitation tools.
3. Formulation of a Simulation Model
   - **Specification** of structure, decision rules.
   - **Estimation** of parameters, behavioural relationships, and initial conditions.
   - **Tests** for consistency with the purpose and boundary.
4. Testing
   - **Comparison to reference modes:** Does the model reproduce the problem behaviour adequately for your purpose?
   - **Robustness under extreme conditions:** Does the model behave realistically when stressed by extreme conditions?
   - **Sensitivity:** How does the model behave given uncertainty in parameters, initial conditions, model boundary, and aggregation?
   - **Many other tests** *(in Sterman, 2000; Chapter 21)*
5. Policy Design and Evaluation
   - **Scenario specification:** What environmental conditions might arise?
   - **Policy design:** What new decision rules, strategies, and structures might be tried in the real world? How can they be represented in the model?
   - **"What if…" analysis:** What are the effects of the policies?
   - **Sensitivity analysis:** How robust are the policy recommendations under different scenarios and given uncertainties?
6. **Interactions of policies:** Do the policies interact? Are there synergies or compensatory responses?

Source: Sterman (2000)

For simulation exercise, the study used the Vensim DSS (Decision Support System) software version 5.9e (Ventana Systems, Inc., Harvard, MA, USA). Other simulation softwares include iThink; STELLA; Powersim Studio; AnyLogic; etc.).

2.1 Problem Articulation

Discussion in Section 1 indicates a number of pertinent issues in the paddy and rice sector that deserve deeper exploration and explanation. The sector has more or less remained under the same structure since 1971, the year National Paddy and Rice Authority took charge in monitoring the supply and demand of rice to ensure price stability to producers and consumers and the targeted SSLs are met. The contradiction in the policy objectives necessitated the government to institute GMP and fixed ceiling prices to insulate the producers and consumers respectively from the variability of world price. Since paddy farming is not competitive like other crops, it is subsidised to reduce the production cost burden to the producers. In short, the sector is governed by a protectionist policy with continuous developmental and institutional supports. All these have been going on for about six decades.

With the above structural landscape, the sector produces a number of typical behaviour among the important policy variables such as: slow growth of yield and hence production, unchanged realised SSL levels and low return to producers. Despite the continuous increase in subsidies and institutional supports, paddy yield and production increased at a slow growth rate of 1% per year while consumption grows 1.8% annually. This explains for the growing import which grew at an average of 7.6% annually. These phenomena invite the following research questions:

(i) What are the structural and institutional factors and policy paradigms that cause the slow growth in paddy and rice production?

(ii) What are the structural and institutional factors that cause the low productivity and hence low return to paddy producer? *and*

(iii) What are the policy options needed to induce growth, equity and sustainability of the sector?

2.1.1 Objectives of the Study

The objectives of this study are as follows:

(i) To identify the structural and institutional factors and policy paradigms that cause the slow growth in paddy and rice production;

(ii) To examine the structural and institutional factors that cause the low productivity and hence low returns to smallholders;

(iii) To develop a system dynamics model that captures the relationships between the structural elements and behaviour and performance, of the paddy and rice sector; and

(iv) Based on the above findings, simulations are to be conducted to identify alternative policy interventions in the industry.

2.1.2 Key Variables and Time Horizon

The study identifies the following key variables as important in steering the paddy and rice system towards growth and sustainability. They are: paddy yield, cropping intensity, area, production, consumption of rice, farmers' income, SSL, R&D, extension services, input cost (labour and non-labour), local input sector, subsidies (input and output) and paddy price.

The model time horizon is extended up to 2050 for simulation purposes. The current problems faced by the industry can be traced to as far back as the 1980s. Hence the study refers to the behaviour within the past 36 years (1980 – 2016) as the reference mode for the simulation exercise.

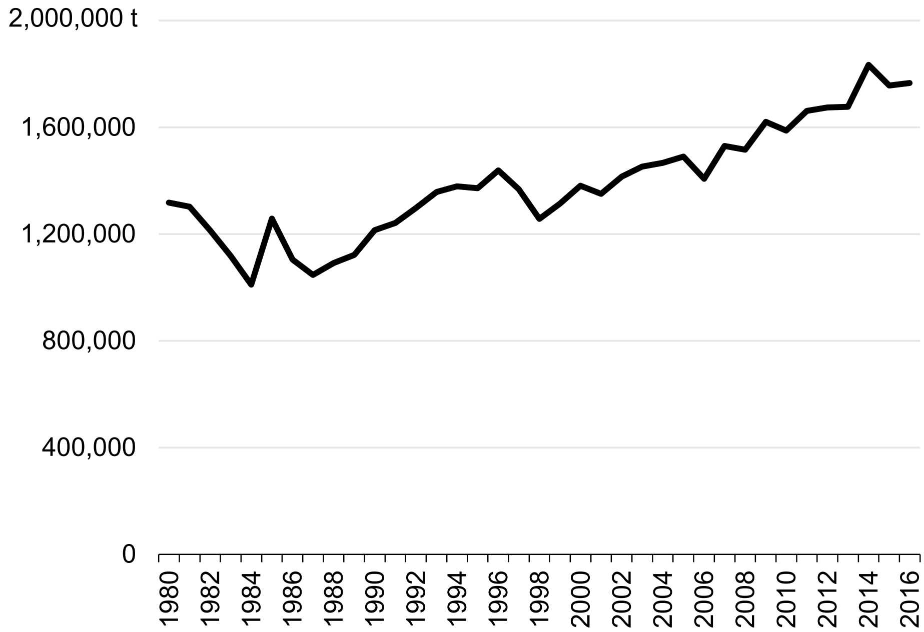
2.1.3 Reference Mode

Reference mode is defined as a set of graphs and other descriptive data showing the development of the problem over time. The graphs indicate or describe the problem dynamically, that is as a pattern of behaviour, unfolding over time, which shows how the problem arose and how it might evolve in the future. The following paragraphs provide relevant reference mode for the problem articulated above.

Rice Production

Figure 2.2 depicts the behaviour of rice production in Malaysia between 1980 and 2016. Overall, the trend is increasing where the ARoG between the reference periods is 1% per annum which is lower than that of rice requirement at 1.8%. The ARoG was negative at 0.3% in the 1980s due to the country's focus on industrialisation effort but later picked up again to 1.4% in the 1990s. Beyond 2008, the production picked up a bit to an average annual growth rate of 1.7%. This was driven by heavy subsidies injection after the 2008 crisis.

Figure 2.2 Production of Rice (t), 1960 – 2016

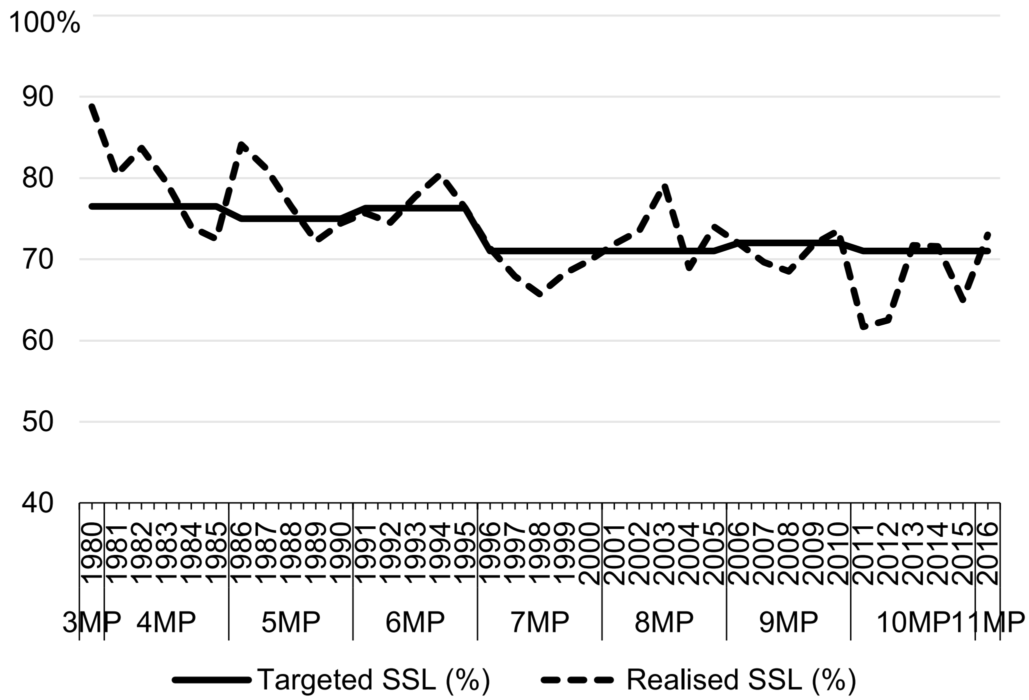


Source: Time Series: Paddy, DOS (2017a)

Self-sufficiency Level

The targeted and realised SSLs under various five year Malaysia plans are depicted in Figure 2.3. The targeted levels averaged 76% between 1980 and 1995 or the Third to Fifth Malaysia Plan periods. However, the targets have been revised a little lower to an average of 71.5% between 1996 – 2016 or the period spanning the Sixth to Eleventh Malaysia Plans. The realised SSLs seem to follow the targets in that the trend is declining but the levels fluctuate year to year.

Figure 2.3 Targeted and Achieved SSL under Various Policy Plans (%), 1980 – 2020

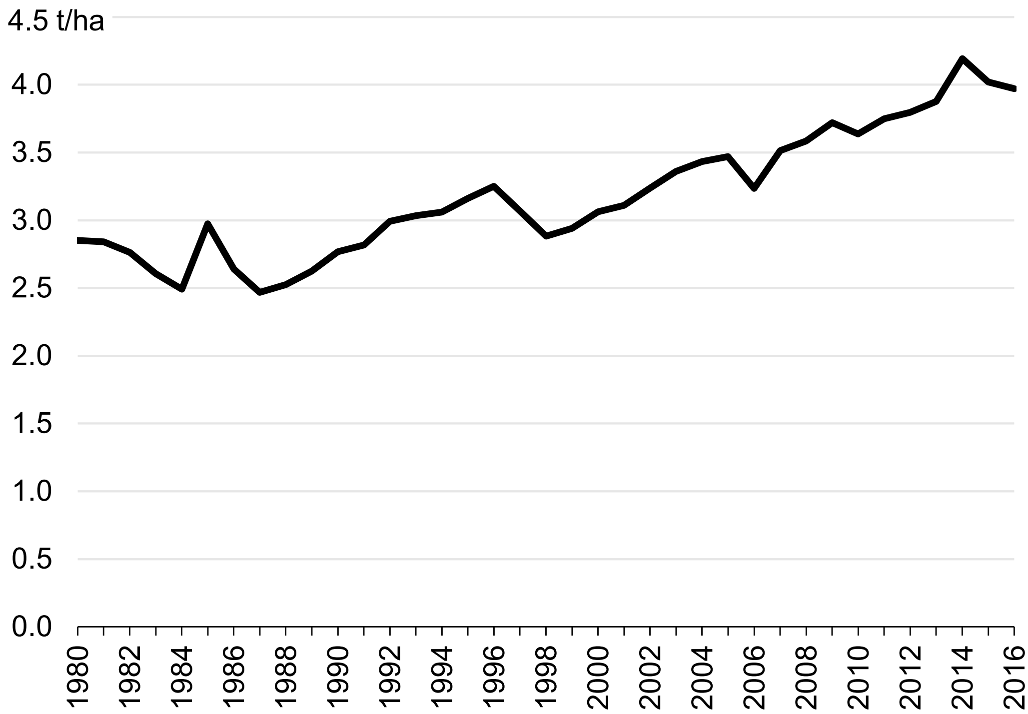


Source: Malaysia (1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015)

Paddy Yield

Yield is an important parameter that determines production and later returns to farmers. The average annual growth rate for paddy yield for the period of 1980 to 2016 is estimated at 1.1% (Figure 2.4). However, there are variations of ARoG between periods. For instance, the ARoG for the period of 1980 – 1990 was very low at 0.06% It later increased to 1.1% (1991 – 2000) and to 1.8% (2000 – 2010). Since 2008, the year when the government stepped up subsidies three-folds, the ARoG was reduced to 1.4%.

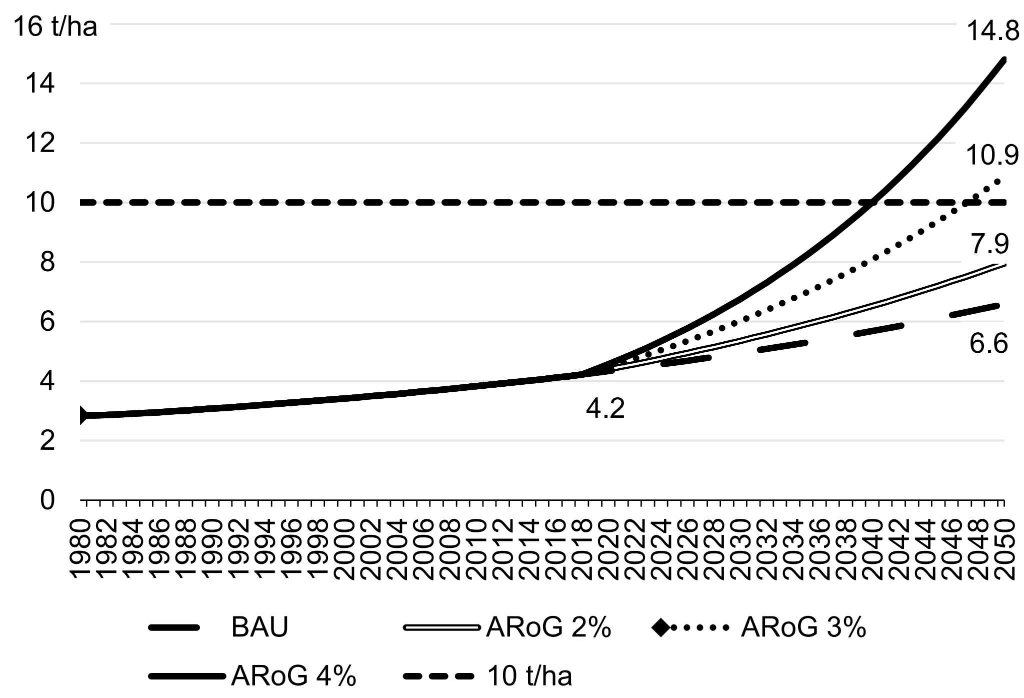
Figure 2.4 Yield of Paddy (t/ha), 1980 – 2016



Source: Time Series: Paddy, DOS (2017a)

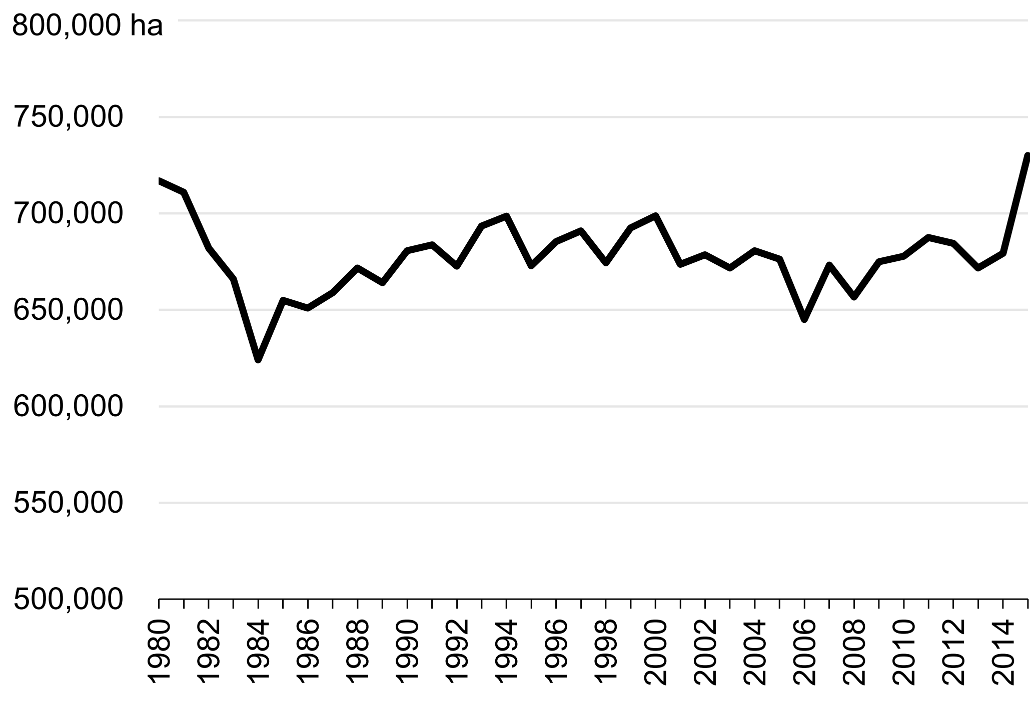
Figure 2.5 indicates the probable paths of yield trends in the future based on the indicated ARoG rates. Assuming the base value of yield of 4.2 t/ha in 2018 and the current rate of ARoG of 1.1%, the targeted yield of 10 t/ha as stipulated in Ninth Malaysia Plan is unattainable by 2050 (Figure 2.5). Similarly an AroG of 2% will not take Malaysia to the intended target. However, with an ARoG of 3%, Malaysia will be able to reach the 10 t/ha target by 2048, or earlier (2040) with an ARoG of 4%. This simple analysis suggests the need to step up the growth fraction or ARoG to increase yield and hence production.

Figure 2.5 Projection of Yield by Growth Fraction (t/ha), 1980 – 2050



Source: Authors

Figure 2.6 Paddy Area (ha), 1980 – 2015



Source: Time Series: Paddy, DOS (2017a)

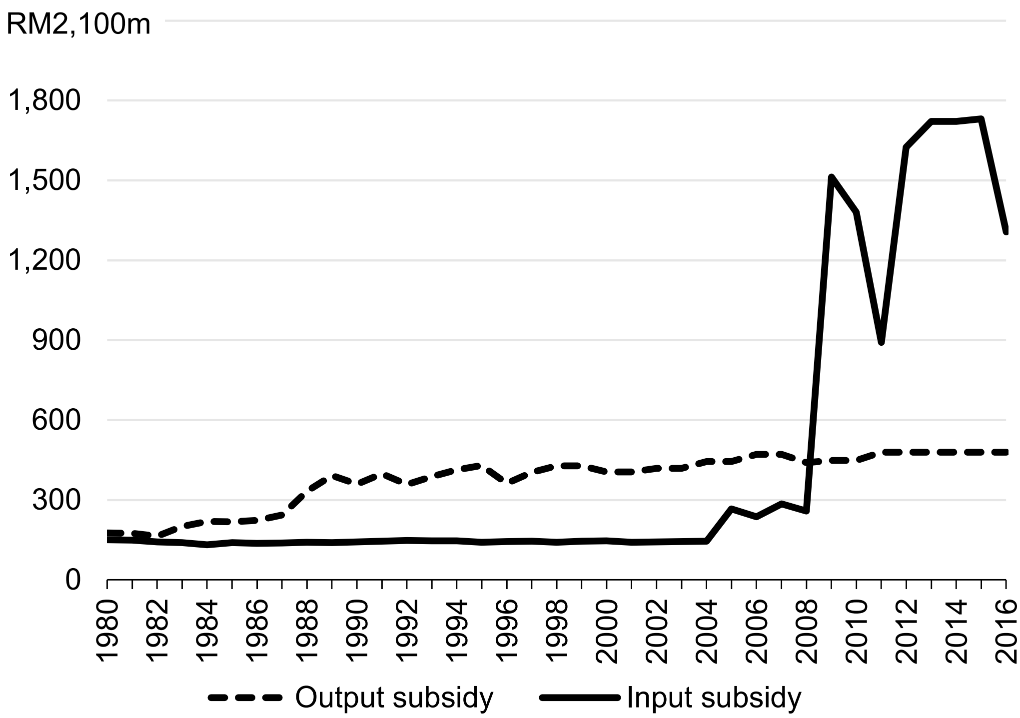
Paddy Area

The paddy area showed a slow decline at an ARoG of 1% for the period between 1980 and 2016 (Figure 2.6). However, there are variations of ARoGs between periods. The area declined at an ARoG of 0.5% during 1980 –1990, but picked up slowly (with an ARoG of 0.3%) in the following decade. It continued to decline but with the stepping up of subsidies in 2008, the area responded with a positive ARoG of 0.2% after 2008.

Input and Output Subsidy

The value of input and output subsidy distributed to the farmers are shown in Figure 2.7. This figure indicates a few pertinent observations. First, the total subsidies have increased from RM176m in 1980 to RM1,786m in 2016, an increase of 180%. Second, there is a shift in the composition of subsidy types. For instance, in the 1990s, the average of output subsidy (Paddy Price Subsidy Scheme) was RM397m compared to RM77m for input subsidy. However, after 2008, the average for input subsidy has increased dramatically to RM1.349b while the average for output subsidy increased slightly to RM468m. In terms of percentage, the share of output subsidy was 84.2% in the 1990s compared to input subsidy of 15.8%. Between 2000 – 2008, the share of input subsidy has increased to about one-third. After 2008, its share has increased further to almost three-quarter of the total subsidy allocation. Third, after 2008 a number of new input subsidies were introduced besides the normal NPK provided since 1979. The new subsidies include: Paddy Seed Subsidy, Paddy Production Incentive Scheme and Fertiliser Subsidy and Pesticide for Hill Rice (Table 1.1).

Figure 2.7 Input and Output Subsidy Allocation (RM m), 1980 – 2016



Source: MOA (2016) & Fatimah et al. (2019)

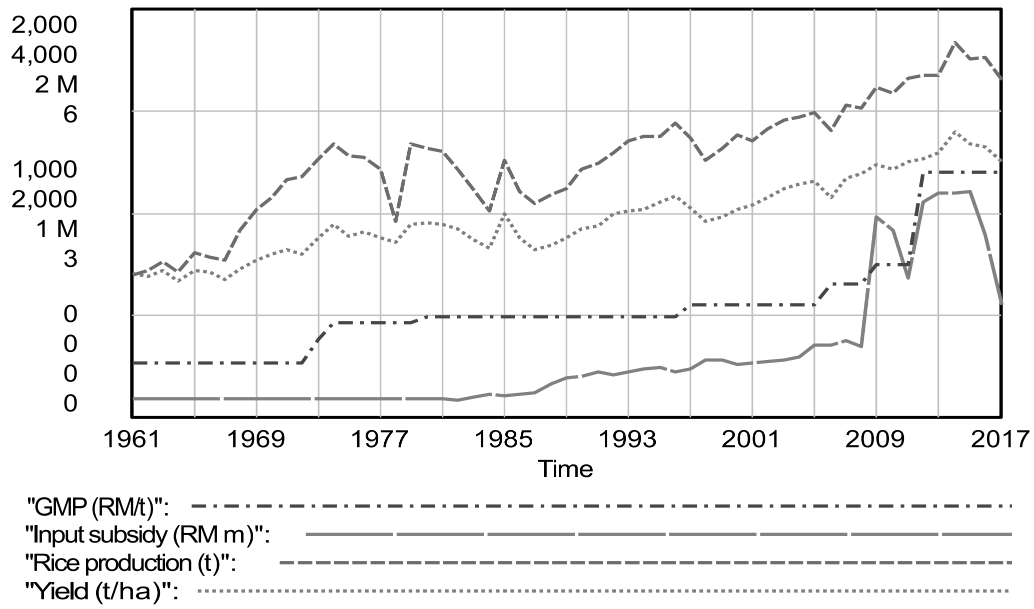
Other Issues

Other issues affecting the sector include farmers' income, undeveloped internal capacity and inequitable distribution of profit along the supply chain. Due to lack of time series data, they are not ready to be used as reference modes but they need mentioning as they are affecting the farmers and system's behaviour. The paragraphs below briefly discuss these issues.

Farmers' Income

Generally, farmers are responsive to price in that production[56] of rice increases as GMP level subsidy allocation are stepped up. Despite this, as discussed earlier, the returns to farmers are still low as 90% of them are categorised in the B40 category (MOA). The major determinants of farmers' income are yield and cost of production. As discussed earlier, the yield increment is still low. The technical efficiency scores for granary areas such as MADA, IADAs (Barat Laut Selangor and Penang) are in the range of 75% – 78% indicating rooms for further improvement[57]. Amin *et al.* (2010) indicated that only 35% of paddy farmers in MADA and IADA-Penang achieved technical efficiency while KADA (4%). Cost of paddy production has increased over the years due to mechanisation and higher input cost[58].

Figure 2.8 Rice Production (t), Paddy Yield (t/ha) and GMP (RM/t), 1960 – 2016



Source: FAOSTAT (2017a) (for production of rice) and MOA (2016) for GMP

56 The supply (production) elasticity is estimated at 0.13 (Tengku Ariff and Ariffin (2001)).

57 For instance, only 45% of farmers in Barat Laut Selangor achieved technical efficiency, MADA and IADA (Penang) (35%) and KADA (4%) (Amin et al. (2010)). Technical efficiency, i.e. how much more output can be produced with the given levels of inputs and current technology (FAO (2005)).

58 The total cost od paddy production of a farm with yield 3.6 t was estimated RM631/ha in 1983 (World Bank, 1984), increased to RM2,188/t in 2006 (Amin et al. (2010)) and RM2,492 in 2018 (Fatimah et al. (2019)).

Undeveloped Internal Capacity

One of the factors that lead to the increase in the cost of paddy production is the high dependence on import for almost all input items. However, little effort has been made to develop them locally. These items include: fertilisers, pesticides, weedicides and machines. Fossil fuel based inputs are highly susceptible to crude oil prices in the international market. Malaysia may not be able to compete with big agribusiness multinationals, but efforts to produce fertiliser using local bio-mass could provide the starting point for local input production. Similarly, the development of small machines that are suitable for small farms are necessary to reduce cost and hence improve efficiency.

Amin *et al.* (2010) indicate that the input market for fertiliser is not competitive as its distribution is centralised through National Farmers Association (NAFAS) in the last four decades[59]. Uncompetitive market provides limited options to farmers and high cost of transactions. As shown by Amin *et al.* (2010) about a third of the fertilisers delivered was not on time and more than one-third of farmers reported that some of the fertilisers were not suitable for their soil conditions (as the formula prescribed is standardised for all types of soils). The average delay of input delivery ranged from 14 – 222 days in 2016 – 2018[60]. This uncompetitive structure may need to be restructured for a more competitive market and to encourage local input production.

2.2 Formulation of Dynamic Hypothesis

2.2.1 Initial Hypotheses

There is a clear need to understand the dynamics that are causing the slow growth of the paddy and rice industry. At this juncture, an initial hypothesis is necessary to guide the consequent modelling process of the sector. It appears that the resultant "slow growth" is an outcome of a "vicious" circle that drags the industry into the trap of continuous sluggishness and high cost to the economy (to the public sector and producers). The evidence is pointing towards persistent low returns to producers while the cost of subsidies continues to rise. The vicious circle can be explained as follows. A low yield leads to low returns and hence little saving at the farm which reduces capital formation. With little capital, the farmer has no capacity to increase farming efficiency which drags down his productivity and returns further. It is clear that is a "vicious" circle that is basically a reinforcing loop that amplifies change over time. This vicious circle on the other hand is responding to the other elements in the production system which include R&D, extension system, input market, policy instruments and rice consumption. This is a simplified endogenous explanation of the phenomenon i.e., the slow growth problem arises from within the production system. In other words, one needs to specify how the system is structured and the decision rules of interaction in the system. This will enable one to explore how the structure and decision rules affect the behaviour and also the possibility of changing the former to produce a different behaviour.

59 Amin et al. (2010)
60 National Audit Department (2019)

Based on the earlier discussion, the following dynamic hypotheses are proposed here. They are:

(i) The institutional factors, particularly RDE, are crucial in affecting the realised paddy yield. R&D has the potential to produce a much higher yielding variety as well as increasing crop intensity to increase production. Similarly, an efficient extension reduces the gap between experimental and realised yield on the farm.

(ii) Input sector development may help reduce the cost of paddy production and hence increase the producer's returns.

2.2.2 The Model Scope

For the paddy/rice model, we propose to look at three subsystems within the paddy/rice sector.

The first is the subsystem that determines the Rice requirements. This requirement is influenced by the total population and per capita consumption of rice. In this model, these variables are referred to as exogenous as they are independent i.e. not determined within the model.

The second is the RDE subsystem. Although R&D may also be involved in the consumption subsector, for example the reduction of losses in storage and transportation, this aspect of R&D is not examined here. The impact of RDE on production of paddy and subsequently rice is wide ranging. For example potential yield can be improved by the development of new varieties and shorter delay time in extension. New machineries can alter the capital-labour requirement that can improve profitability and overcome the labour shortage in farming. R&D on domestic production of inputs can reduce cost of imported inputs. Similarly R&D has the potential to increase cropping intensity. For the study purposes, we focus on three spheres of RDE namely; yield improvement, cropping intensity enhancement and reduction in delay time between potential and realised yield.

The third is the Farming subsystem. This subsystem is involved in turning inputs (land, labour, capital, and input) into paddy. Note that in reality paddy farmers are involved in other activities beside paddy. The interrelationships between these other activities and paddy farming are not considered here.

2.2.3 The Causal Loop Diagram

The causal loop diagram or CLD shows the major relationships (links) between the variables in the three sub-systems namely: Rice requirement, RDE, and Farming (input and revenue) (Figure 2.9). It is a simplistic diagram to explain the causal relationship between the three sub-systems. It is used as general guidelines to prepare the stock and flow diagram which quantifies those relationships in a detailed manner.

The *Rice requirement sub-system* comprises two variables, per capita consumption and Total population. *Total population* is modelled as a reinforcing loop. *Rice requirement* is the product of *Total consumption* multiplies by the *Per capita consumption*. The two variables are exogenous and impact SSL positively.

SSL[61] influences the RDE subsector by the pressure it exerts on *Physical paddy land* and *R&D capacity*. Higher *SSL* level reduces the *Physical paddy land* but increases the *paddy planted area* and *vice versa.* Similarly lower *SSL* increases the pressure on *R&D capacity* to deliver improved *Cropping intensity* and higher *Potential paddy yield per ha per crop.* As for the former, improved *Cropping intensity* increases the *Paddy planted area* and hence *Total rice production per year.* This in turn determines the *SSL* level after taking into account the *Rice requirement.* After this, the loop continues following the path described earlier.

R&D capacity is instrumental in producing potentially high yielding variety of paddy. However, the realised yield is a function of extension which is translated into *Time to implement potential yield.* As shown in the figure, the *Paddy yield realised per ha per crop* is determined by the time to implement potential yield as well as the labour and input use from the Farming: Input sub-system. Note that realised paddy yield influences paddy produced, sold and rice production. This leads to the determination of the *SSL* ratio which completes the RDE sub-system.

The shared variable *SSL* also influences the Farming sub-systems (input and revenue) through the pressure on the government to review the Non-labour (NL) input and output subsidies. The *Subsidy on NL input* affects *Expected variable cost* and *Expected profitability per ha per year.* The latter determines the *Desired labou*r and *NL input use* and realised paddy yield located in the RDE sub-system.

The output subsidy affects *Farmer revenue* and *Expected profitability per ha per year*[62] in the Farming: revenue sub-system. As in the earlier case, this variable determines the desired input use (labour and non-labour) in the Farming: input sub-system and realised paddy yield in the RDE sub-system.

The paddy sold determines the *Farmer revenue* and *Expected profitability per ha per year* and hence the desired NL input use. The consequent causal lines are as above.

The above describes briefly the causal relationship between major variables in the paddy and rice model. Each sub-system behaves differently either reinforcing or balancing (Appendix 2). The following paragraphs explain the loops in the paddy and rice system.

Reinforcing loops:

R1: Population loop determines the country's *Rice requirement* or consumption which is the denominator of the *SSL* index. Higher population growth leads to higher *Total population* and hence *Rice requirement.*

R2 & R3: R2 refers to *NL input use and profitability loop.* It describes the feedback relationships between the use of NL input on profit. An increase in input use would increase the *Paddy yield realised, Paddy produced* and *Paddy sold per ha per crop* which

61 For simplicity, the discussion utilises the *SSL* instead of Smoothed *SSL* as shown in Figure 2.9 as the major variable that drives the RDE system. The *SSL* is smoothed by 2 years which indicate the length of time or delay necessary to derive an *SSL* level that minimises irregularities in the system (Kirkwood, 1998).

62 Expected profitability per ha per year is basically a markup ratio calculated as (Expected revenue per ha per year-Expected variable cost per ha per year)/Expected variable cost per ha per year

increase *Farmer revenue per ha per year*. An improvement in *Farmer revenue per ha per year* increases the *Expected profitability per ha per year* and *NL input use index per ha per crop* which closes the loop.

R3 is *Labour use and profitability loop*. It traces the circular causality between labour use and profitability. An increase in *Expected profitability per ha per year* may increase *Labour use* and *Paddy yield realised per ha per crop* in a reinforcing manner.

Balancing loops:

B1: *SSL and Land*. This loop traces the circular causality between *SSL* and land usage. An increase in *Rice requirement* reduces the *SSL ratio* as well as *Expected SSL* and vice versa. A reduction in the *SSL* increases the demand for paddy area to be taken from the fixed *Physical paddy land.* While physical land is reduced, the Paddy planted area increases which leads to an improvement in *Total rice production per year* and *SSL* which completes the loop.

B2: R&D and crop intensity[63] loop explains the feedback relationship between *R&D capacity*, *Cropping intensity* and *SSL*. A reduction in the *Expected SSL* leads to an increase in *R&D* capacity and hence *Cropping intensity*, *Paddy planted area* and *Total rice production per year* and *SSL.* However, an increase in the *SSL* in turn reduces the *R&D capacity* and the loop goes on until stability is achieved that is the targeted *SSL* is realised.

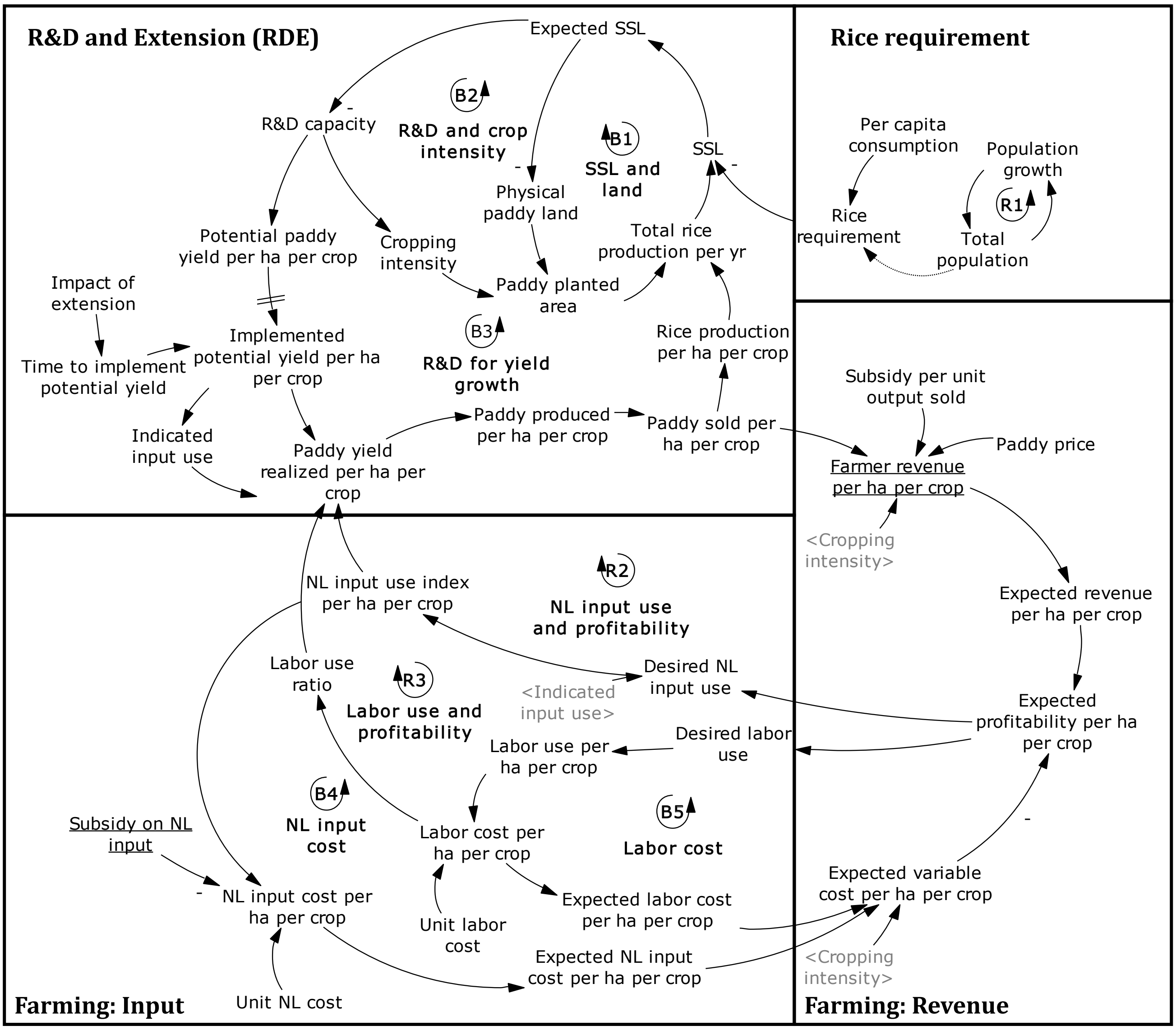
B3: R&D for yield growth loop indicates the circular causality flow of *SSL*, R&D to improve yield and back to *SSL*. As in the above case, a reduction in the *SSL* causes the *R&D capacity* to improve *Potential paddy yield per ha per crop*. This in turn increases *Implemented potential yield per ha per crop* which may take some time (lag or delay) to derive the *Paddy yield realised per ha per crop* at the farm. The consequent impact of the increase in yield include: a positive move of variables such as *Paddy produced per ha per crop*, *Total rice production per year* and *SSL,* Then, as described in B2, the loop goes on until stability is achieved when the targeted *SSL* is realised.

B4 & B5: *NL Input cost* and *Labour cost loops* indicate the feedback interactions between input costs (labour and non-labour) and profit and revenue. In the case of B4, an increase in the *Expected profitability per ha per crop* leads to an increase in the *Desired NL input use*. This increase is reflected as *NL input use index per ha per crop.* This index determines the *NL input cost per ha per crop* and finally the *Expected variable cost per ha per year.* The difference between the expected revenue and variable cost gives the expected profitability which completes this loop.

In the case of B5, a similar relationship holds but with reference to labour input. Expected profitability determines the desired and actual labour use. This in turn influences the labour cost and the consequent variable cost and profitability.

63 Crop Intensity: The fraction of the cultivated area that is harvested. The cropping intensity may exceed 100 percent where more than one crop cycle is permitted each year on the same area (FAO (2019)).

Figure 2.9 The Paddy-Rice Model Causal Loop Diagram (CLD)



2.2.4 The Stock and Flow Diagram

While the CLD shows the links and feedback loops in the model, the stock and flow or S&F diagram shows the links and feedback loops in further detail. Variables can be divided into stocks, representing levels or accumulations, and flows, the rates either add or subtract from stocks. Stocks are shown as rectangles while rates affecting the inflow and outflow of stocks are shown as valves. Other variables, constants, parameters and auxiliaries have no particular symbols in Vensim. For easier reading, the mentioning of the unit and time element of a variable is omitted wherever necessary. The implied unit and time dimension should be intuitive.

The upper half of Figure 2.11 shows the Rice requirement and RDE sub-systems. The *Per capita consumption* is modelled as a stock variable decreasing over time[64] to reflect the

64 Based on historical data (1980-2014): Rice requirement over Total population.

influence of changing consumer preference mainly due to their increasing income and lifestyle. *Total population* is an increasing stock variable with the changes of fraction from 2.6% to 1.3% for 1980 to 2050 respectively[65]. Both variables influence the *Rice requirement*.

The RDE sub-system contains four stock variables as seen from the number of rectangles. The two main ones being the *R&D capacity index* and *Cropping intensity*.

The *R&D capacity index*[66] which is determined by the *Change in R&D*, is an index variable with a starting value of 100 in the initial period and an annual growth rate of 6.7%. The index is instrumental to improve yield as well as cropping intensity (see also Figure 2.9). The relevant loop for yield is called *R&D for yield growth.* Basically, the index affects potential yield and the time to implement it, both of which determine the realised yield. This in turn affects rice production, SSL, desired R&D and R&D capacity index which completes the loop.

The relevant loop for cropping intensity is called *R&D and crop intensity.* The *R&D capacity index* affects the *Cropping intensity* and hence *Paddy planted area*. When *Paddy planted area* is multiplied with *Paddy yield realised per ha per crop, Rice production per ha per crop* is derived, this in turn affects the *SSL ratio*, *Desired R&D* and *R&D capacity index* which closes the loop. *Cropping intensity* is based on a starting value of 1.6 in the initial period and experiences an annual growth rate of 1.7%.

The lower half of Figure 2.10 depicts the production sub-system which has five stock variables, not including the *Paddy price* stock variables (on the right side of the figure). *Paddy price* variable is calculated based on the stock and flow of *Paddy price policy after 2018* and *Paddy price BAU after 2018*. *Paddy price policy after 2018* is determined by *Paddy price policy before 2018* where the price started from RM496/t in 1980 to RM1,200/t in 2014[67] respectively. After 2018, the *Paddy price change growth* is at 3%[68] every year until 2050 (RM1,652). Hence, *Paddy price* influences *Farmer revenue per ha per year* which is modelled as a growing variable to reflect increasing paddy price over time. Note that *Farmer revenue per ha per year* is also influenced by *Subsidy per unit of output sold*.

Paddy price influences the stocks of *NL input use index* and *Labour per ha per crop* through the *Expected profitability per ha per year*. The other stock variables are *Unit NL cost after 2018* and *Unit labour cost*. The *NL input use index per ha per crop* is an index variable with an initial value of 100 and growing at 1.4% per year.

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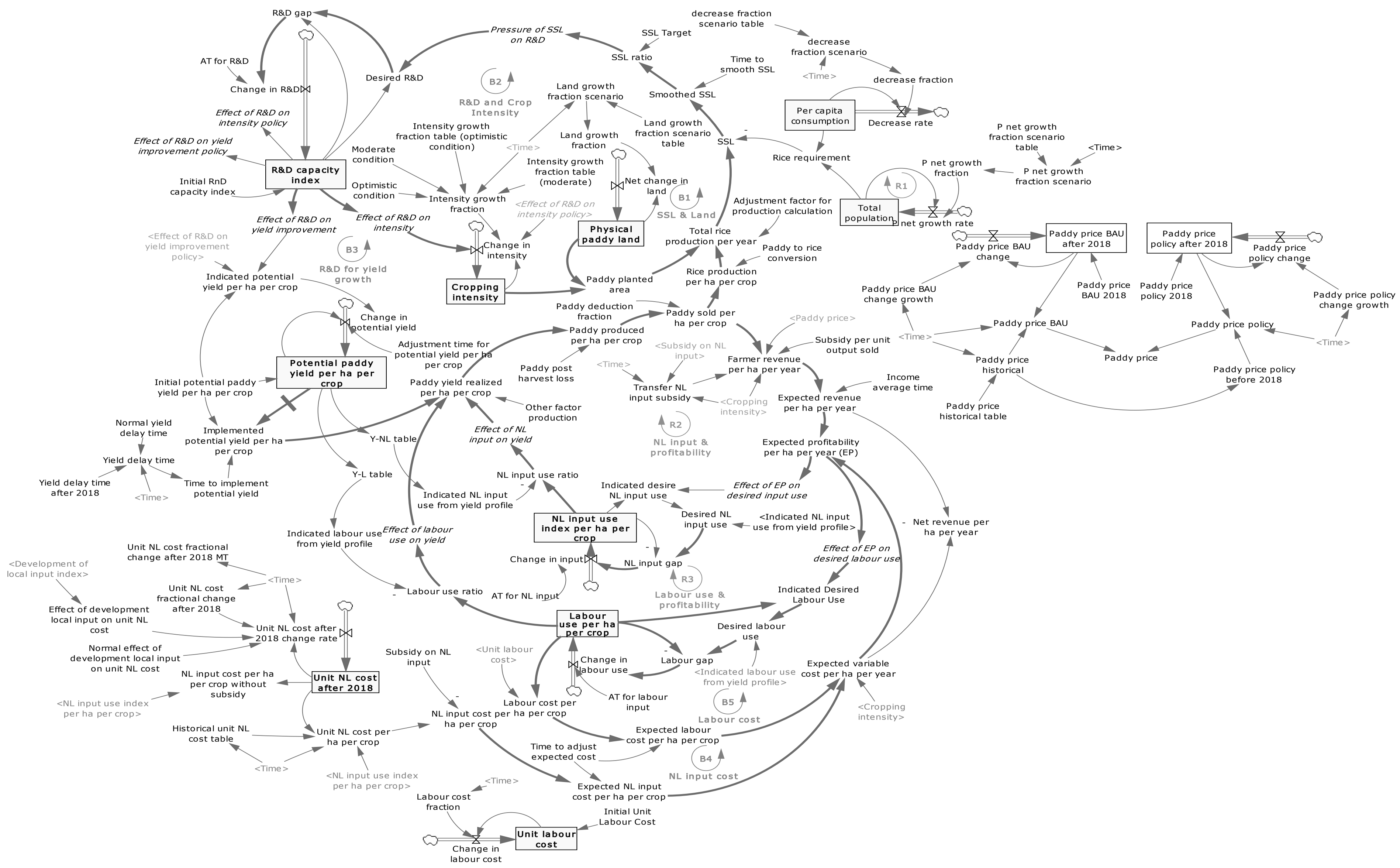
65 The ARoGs are estimated from data on population (DOS, (2017b)).

66 Index: Soft variables (capturing qualitative variables) that do not have well-established units of measure, measurement error arises from two additional sources: the definition of a unit of measure and the creation of a measurement tool. These can be measured based on surveys, focus group discussions, and previous studies.

67 Paddy price is based on historical data (1980-1997=RM496); (1998-2005=RM550); (2006-2007=RM650); (2008-2013=RM750); (2014-2017=RM1,200). Source: MOA (2016).

68 The 3% growth per annum is based on the average rate of annual growth of border price of paddy since 1980 to 2016 (Source: www.irri.org).

Figure 2.10 The Stock and Flow Diagram of Paddy Model



2.3 Formulation of Simulation

2.3.1 Key Drivers

Total population, based on historical data available, and for simplicity, is aggregated into a single stock with a *P net growth rate*. Then, Total *population* and its *P net growth rate* form a positive feedback loop, or a reinforcing loop. The net growth is assumed to be dependent on the *Total population*. In general, such dependence is possibly nonlinear. However, for simplicity, proportionality is assumed here for our medium-time range of simulation until 2050.

Total population= INTEG (P net growth rate, 13,879,000[69]) [2.1]

P net growth rate=P net growth fraction*Total population [2.2]

Based on historical data, *P net growth fraction* is estimated to be 0.02 (meaning 2% per year[70]).

Formulated in this way, *Total population* follows an exponential growth. *Total population* together with the average *Per capita consumption* determines total *Rice requirement*.

Rice requirement = Per capita consumption*Total population [2.3]

Per capita consumption, on the average, is in general not a constant, and declines somewhat gradually with increasing income. Based on data available, *Per capita consumption* in 1980 is estimated at 107 kg per year per person in Malaysia, and a slight decline in annual consumption per capita is assumed to be 0.2% per year[71].

Total annual rice requirement with nearly exponential growth over time acts as a key driver to force *Total rice production per year* to adjust up to achieve a suitable level of Self-sufficiency level (*SSL*). Although there are variants of *SSL*, the simplest form of *SSL* is used in our model to avoid extra variables to be used.

SSL = Total rice production per year/Rice requirement [2.4]

2.3.2 Institutional Responses

In general, as long as *SSL* remains under a sustainable level, agricultural planners, besides relying on import to close the gap between domestic supply and domestic demand, they have no choice but to try to increase domestic rice production by any possible methods (normally the quickest and least expensive). Levels of determination toward self-reliance may vary from country to country, depending on concepts of rice security. As for Malaysia, where land suitable for rice production is limited for expansion, increasing paddy yield is inevitable to increase production.

Malaysia may emulate best practices from other countries that have achieved higher yield growth. These include; first, short crop cycles to increase cropping intensity, through R&D to develop new varieties that can be harvested in shorter duration. Second, develop

69 This refer to population figure in 1980. Source: DOS (2017b).
70 Source: Calculated from DOS (2017b)
71 Source: MOA (2016).

varieties that are resistant to diseases, to unfavourable weather conditions such as droughts, floods; and can be adaptable to adverse impacts from climate change, and also to various type of local lands such as uplands, slope lands and other type of problem lands. High yielding varieties must be continuously produced to meet the market and environmental challenges. These pervasive responses are captured in the model and formulated based on increasing *R&D capacity index* stock under the pressure of relative low level of *SSL*.

First, expectation of *SSL*, which is normally based on its recent trend of *SSL*, will exert a pressure on the need to further enhance R&D to some desired level to be adjusted to with some adjustment time required.

Smoothed SSL = SMOOTH (SSL, Time to smooth SSL) [2.5]

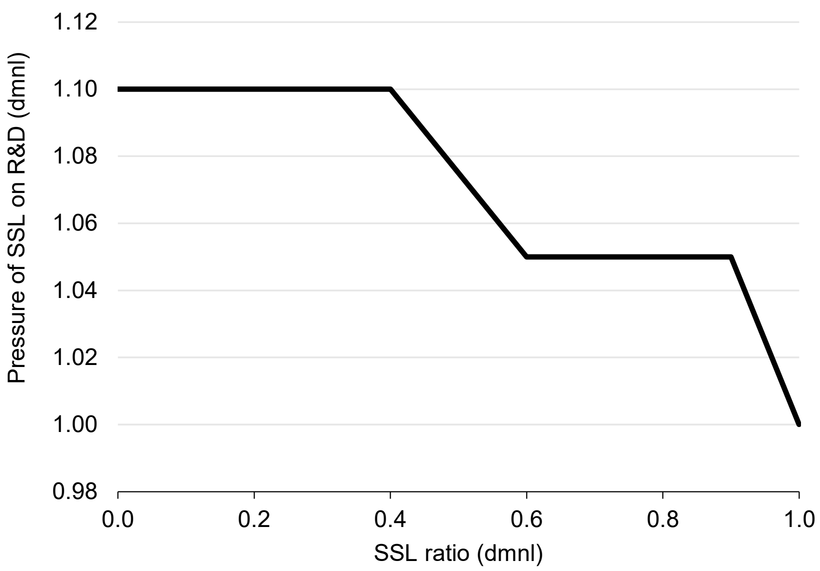
SSL ratio = MIN (SSL Target, Smoothed SSL/SSL Target) [2.6]

Pressure of SSL on R&D = WITH LOOKUP (SSL ratio,([(0,0.9)-(1,1.2)],
(0,1.1),(0.2,1.1),(0.4,1.1),(0.6,1.05),(0.8,1.05),(0.9,1.05),(1,1))) [2.7]

The function *f*(*Smoothed SSL*) represents a behavioural relationship between only three variables: *Smoothed SSL* and its *SSL ratio* and *Pressure of SSL on R&D*[72]. Its shape must be downward sloping (which means that less *Smoothed SSL* leads to more *Pressure of SSL on R&D*), and passes the normalized point (1,1), as *Smoothed SSL* declines further.

Figure 2.11 shows a typical function of f(Smoothed SSL). Such a function can use an analytic form, but it is more flexible to use a sort of table or lookup function. Some reference curve (or policy reference curve) can be used to adjust the shape[73].

Figure 2.11 Pressure of SSL on R&D (dmnl[74])



72 Based on the base model (Figure 2.11)
73 The shape is based on previous studies, FGD, and surveys.
74 dmnl refers to dimensionless.

SSL ratio (dmnl)	Pressure of SSL on R&D (dmnl)	Decrement
0	1.1	
0.2	1.1	0
0.4	1.1	0
0.6	1.05	0.05
0.8	1.05	0
0.9	1.05	0
1	1	0.05

Source: Calibrated from the model

The *Pressure of SSL on R&D* is a response of R&D to a given change in *Smoothed SSL*. The responsiveness of R&D to *Smoothed SSL* depends on R&D policy at the national level. Some countries are more responsive, but Malaysia is not so proven by the slow growth of productivity despite the Green Revolution in the 1970s (Figure 1.2) while countries like Vietnam and Indonesia have achieved an average of 6 t/ha[75].

R&D capacity index is formulated as an aggregate stock using an index of 100 at 1980 for simplicity. The index is changed through the rate called *Change in R&D*. The *Change in R&D* is modelled through an adjustment process to close the gap between the *Desired R&D* and actual *R&D over an Adjustment time (AT).* However, we do not know the *Desired level of R&D*, the so-called hill-climbing heuristic is used to determine the *Desired R&D* by anchoring on the current state of R&D, then adjusting in response to the *Pressure SSL on R&D*, which represents the gradient of the hill and indicates the way uphill.

R&D capacity index= INTEG (Change in R&D, Initial R&D capacity index) [2.8]

Change in R&D=R&D gap/AT for R&D [2.9]

AT for R&D=2 [2.10]

Desired R&D=Pressure of SSL on R&D*R&D capacity index [2.11]

AT for R&D is estimated to be two years to reflect the slow response from the farmers to adjust to the desired R&D level.

R&D capacity index, in general, has effects on (i) *Potential paddy yield per ha per crop* and (ii) *Cropping intensity*. Both of these effects are sloping upward, meaning that more R&D leads to improvements of both *Potential paddy yield per ha per crop* and *Cropping intensity*. Such effects are formulated through table lookup functions.

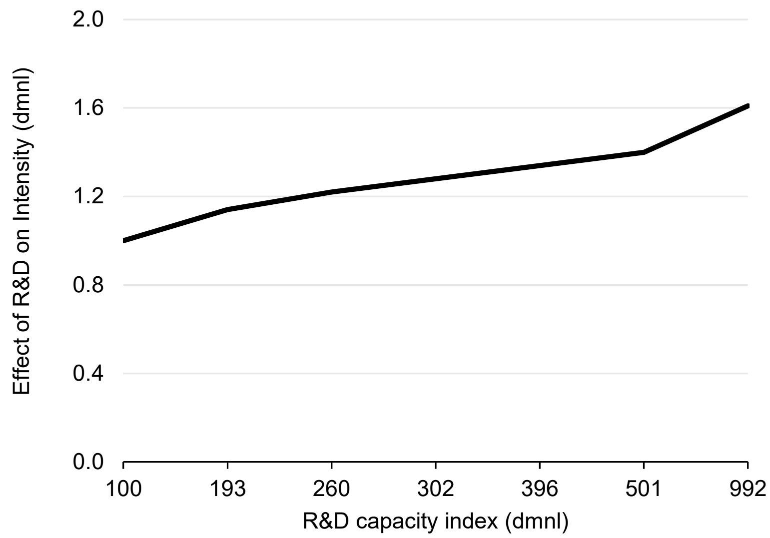
Effect of R&D on intensity= WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.27895),(395.538,1.34211),(500.941,1.4),(991.743,1.61404))) [2.12]

75 IRRI (2017)

Effect of R&D on yield improvement= WITH LOOKUP (R&D capacity index, ([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.2),(400,2.7),(500,3))) [2.13]

The behaviour for the both lookup functions is not so steep, and may saturate. For a given R&D increase, the first level effect would be an increase in *Cropping intensity*, followed by *Potential paddy yield per ha per crop*. For the *Cropping intensity*, the effect is increasing but at a low rate. However in the case of *Potential paddy yield,* the upward movement shows two phases, a moderate increase in the beginning followed by a relatively higher rate of change (Figures 2.12 and 2.13).

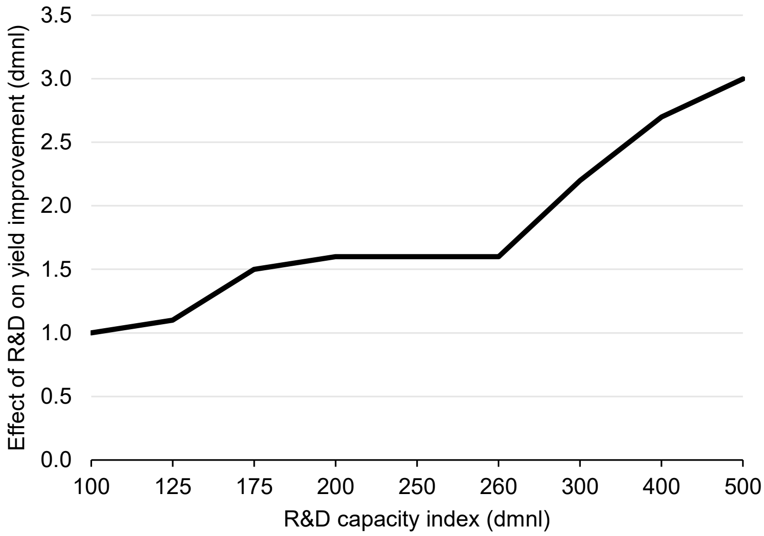
Figure 2.12 Effect of R&D on Cropping Intensity (dmnl)



R&D capacity index (dmnl)	Effect of R&D on Intensity (dmnl)	Increment
100	1	
193.20	1.14	0.14
260.00	1.22	0.08
301.88	1.28	0.05
395.54	1.34	0.06
500.94	1.40	0.06
991.74	1.61	0.21

Source: Calibrated from the model

Figure 2.13 Effect of R&D on Yield Improvement (dmnl)



R&D capacity index (dmnl)	Effect of R&D on yield improvement (dmnl)	Increment
100	1	
125	1.1	0.10
150	1.3	0.20
175	1.5	0.20
200	1.6	0.10
250	1.6	0.00
260	1.6	0.00
300	2.2	0.60
400	2.7	0.50
500	3	0.30

Source: Calibrated from the model

With these two effects, *Potential yield per ha per crop* and *Cropping intensity* are both formulated as stocks that are changed by *Change in potential yield* and *Change in intensity* respectively. These changes are, for simplicity, assumed to be proportional to their stocks, respectively, with some annual change fractions, and are also proportional to respective effects of R&D. Note that these annual change fractions in Malaysia are relatively small, especially for *Cropping intensity* growth fraction, and will be calibrated to fit with reference modes.

Potential paddy yield per ha per crop = INTEG (Change in potential yield, Initial potential paddy yield per ha per crop) [2.14]

Initial potential paddy yield per ha per crop = 2.55 [2.15]

Change in potential yield = (Indicated potential yield per ha per crop-Potential paddy yield per ha per crop)/Adjustment time for potential yield per ha per crop [2.16]

Yield change fraction = Normal yield growth fraction*Effect of R&D on yield improvement*Effect of yield target [2.17]

Normal yield growth fraction = 0.016 [2.18]

Cropping intensity = INTEG (change in intensity,1.6) [2.19]

change in intensity = Cropping intensity*intensity growth fraction*(Effect of R&D on intensity policy) [2.20]

intensity growth fraction[76] = intensity growth fraction table (optimistic condition) (Time)*optimistic condition+moderate condition* intensity growth fraction table (moderate) (Time) [2.21]

intensity growth fraction table (optimistic condition) ([(1980,0.001)-(2050,0.005)],(1980,0.0015),(2020,0.0015),(2050,0.004)) [2.22]

intensity growth fraction table (moderate) ([(1980,0)-(2050,0.002)],(1980,0.0015),(2020,0.0015),(2050,0)) [2.23]

It normally takes time to realize potential yield at the farmer-level. Such a *Delay time* is rather long in Malaysia, which is estimated to be 2 years. This is formulated by a delay process by using SMOOTH function with some adjustment.

Implemented potential yield per ha per crop = SMOOTHI (Potential paddy yield per ha per crop, Time to implement potential yield, 0.95*Initial potential paddy yield per ha per crop) [2.24]

Time to implement potential yield = Yield delay time [2.25]

Paddy yield realized per ha per crop is, for simplicity, assumed to be proportional to *Implemented potential yield per ha per crop* and to *Effect of NL (non-labour) input on yield* and *Effect of labour use on yield.*

Paddy yield realized per ha per crop = Implemented potential yield per ha per crop*Effect of labour use on yield*Effect of NL input on yield [2.26]

Then *Paddy produced per ha per crop* is calculated through variables *Paddy yield realized per ha per crop* and *Paddy post-harvest loss.*

Paddy produced per ha per crop = Paddy yield realized per ha per crop*(1-Paddy post harvest loss) [2.27]

Paddy post harvest loss = 0.2 [2.28]

Paddy sold per ha per crop by farmers is calculated based on *Paddy deduction fraction.*

Paddy sold per ha per crop = Paddy produced per ha per crop*(1-Paddy deduction fraction) [2.29]

76 The simulations are run under two scenario alternatives: optimistic and moderate conditions. The difference between the two is reflected in terms of the intensity of growth fraction tables for the period of 1980 to 2050 as shown in equations 2.22 and 2.23 respectively.

Rice production per ha per crop is multiply of *Paddy to rice conversion* and *Paddy sold per ha per crop.*

Rice production per ha per crop = Paddy to rice conversion*Paddy sold per ha per crop [2.30]

In order to derive *Total rice production per year*, we simply need to multiply *Paddy Planted area* with *Rice production per ha per crop* and *Adjustment factor for production calculation* where crop damages are ignored for simplicity. Note that *Physical paddy land* has remained largely unchanged since 1980.

Total rice production per year = Rice production per ha per crop*Paddy planted area*Adjustment factor for production calculation [2.31]

Paddy planted area = Cropping intensity*Physical paddy land [2.32]

Finally, *SSL* is derived by dividing *Total rice production per year* by *Rice requirement*[77].

2.3.3 Farm-level Responses

At the farm-level, there are two groups of feedback loops based on a hectare of paddy land. The group of positive (or) reinforcing loops consists of two similar loops (R1 and R2) which represent revenues from annual investment on (or use of) key production factors, non-labour (NL) inputs and labour inputs. Likewise, the group of negative (or balancing) loops consists of two similar loops (B1 and B2) which represent production costs from annual investment on (or use of) key production factors, non-labour inputs and labour inputs. Formulations of variables in these two loops are similar. However, there are some differences in the unit of measurement. While labour use can be measured explicitly in man-days, non-labour input is a compound input that includes many different things such as fertilizers, pesticides, *etc*. So an index is used for *NL input use*, which is 100 initially in 1980.

For convenience, we start with the key shared variable which is *Expected profitability per ha per year*. This is from farmers' perspective and then serves as a basis for farmers to make decisions on input uses.

Expected profitability per ha per year (EP) = (Expected revenue per ha per year-Expected variable cost per ha per year)/Expected variable cost per ha per year [2.33]

Note that profitability can be expressed in a number of ways such as mark-up ratio and net benefit. However, in this study, we use the above indicator to avoid possible negative costs due to subsidies. Such expected profitability used here can be understood as perceived profitability and is normalized by the expected revenue to provide a dimensionless ratio.

Farmers are assumed to increase desired input use above current levels when they believe additional inputs to be applied is profitable. Then, after some short time adjustment, level of input uses rises, and, as long as the additional investment is still expected to be

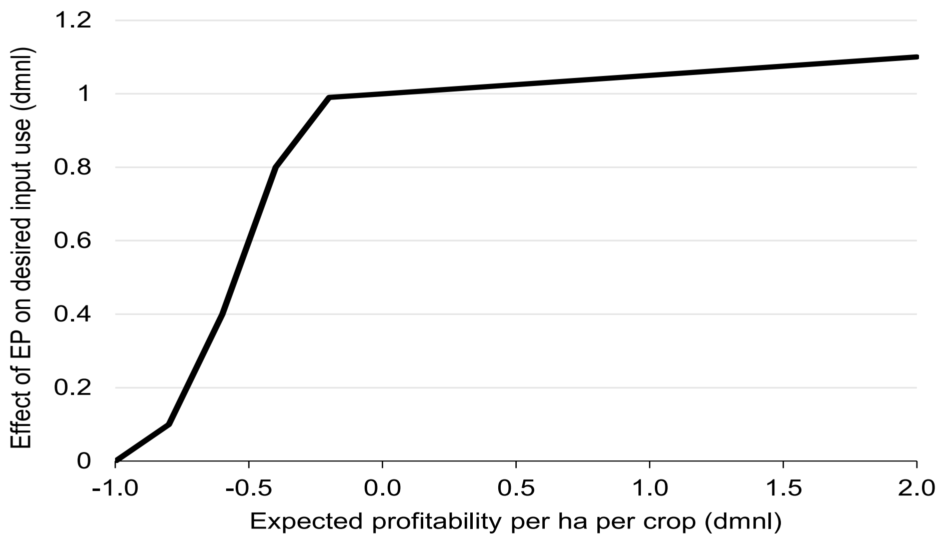
77 SSL is defined here as the ratio of Total rice production (domestic) to Rice requirement (or apparent consumption). Note that this interpretation is different from the formula used by MOA (2016).

profitable, farmers then reset their aspirations and raise their desired levels of input use to a maximum level indicated by yield-input profile. The floating goal for desired levels of input use functions as a hill-climbing heuristic again in which input uses grow as long as profits are higher than normal and fall as long as return on investment falls short. Thus, the formulations of decision rules made by farmers can be formulated as follow.

Desired NL input use=MIN (Indicated desire NL input use, Indicated NL input use from yield profile) [2.34]

Effect of EP on desired NL input use can be presented through a table function as shown in Figure 2.14, which resembles an S-shape.

Figure 2.14 Effect of EP on Desired NL Input Use (dmnl)



Expected profitability per ha per year (EP) (dmnl)	Effect of EP on desired input use (dmnl)	Increment
-1	0	
-0.8	0.1	-0.10
-0.6	0.4	-0.30
-0.4	0.8	-0.40
-0.2	0.99	-0.19
0	1	-0.01
2	1.1	-0.10

Source: Calibrated from the model

The *NL input use index per ha per crop* is formulated as a stock for technical convenience, and is changed by *Change in input*. The *Labour use per ha per crop* is formulated similarly for simplicity.

NL input use index per ha per crop = INTEG (Change in input, 100) [2.35]

Change in input = NL input gap/AT for NL input [2.36]

AT for NL input = 1 [2.37]

NL input gap = Desired NL input use-NL input use index per ha per crop [2.38]

Labour use per ha per crop = INTEG (Change in labour use, 35) [2.39]

AT for labour input = 1 [2.40]

Labour gap = Desired labour use-Labour use per ha per crop [2.41]

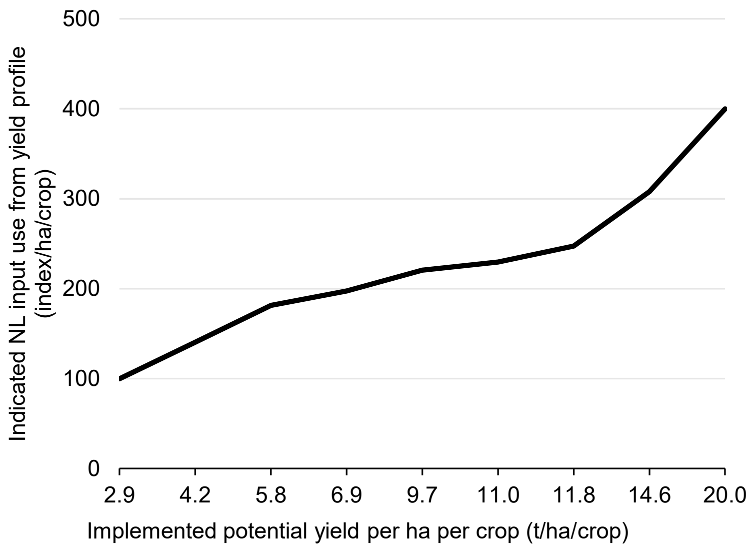
Next, we need to formulate the relationship between *Implemented paddy yield per ha per crop* and required input level requirement to achieve the yield. It can be understood as yield-input curve.

Indicated NL input use from yield profile = Y-NL table [2.42]

Indicated labour use from yield profile = Y-L table [2.43]

Such two curves can be estimated at the farm level and are estimated as shown in Figures 2.16 and Figure 2.17. Note that the shape for *NL input* is upward sloping, but that for labour input is gradually declining because of some impacts of the use farm machineries to reduce labour requirement from 1980 onwards.

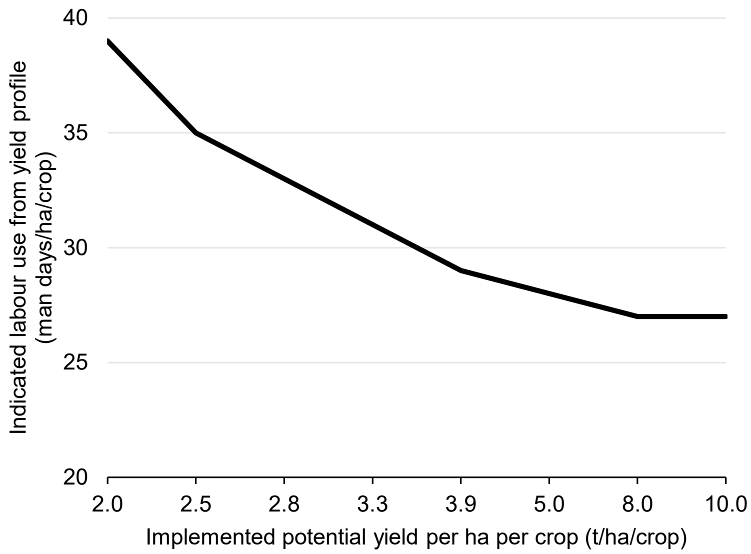
Figure 2.15 Y-NL Table (Yield and NL Input Profile)



Implemented potential yield per ha per crop (t/ha/crop)	Indicated NL input use from yield profile (index/ha/crop)	Increment
2.85	100	
4.18	140.6	40.6
5.84	181.5	40.9
6.85	197.5	16
9.71	220.6	23.1
10.99	229.5	8.9
11.82	247.3	17.8
14.61	307.8	60.5
20	400	92.2

Source: Calibrated from the model

Figure 2.16 Y-L Table (Yield and Labour Profile)



Implemented paddy yield per crop (t/ha/crop)	Indicated labour use from yield profile(man days/ha/crop)	Decrement
2	39	
2.5	35	-4.00
2.8	33	-2.00
3.3	31	-2.00
3.9	29	-2.00
5	28	-1.00
8	27	-1.00
10	27	0.00

Source: Calibrated from the model

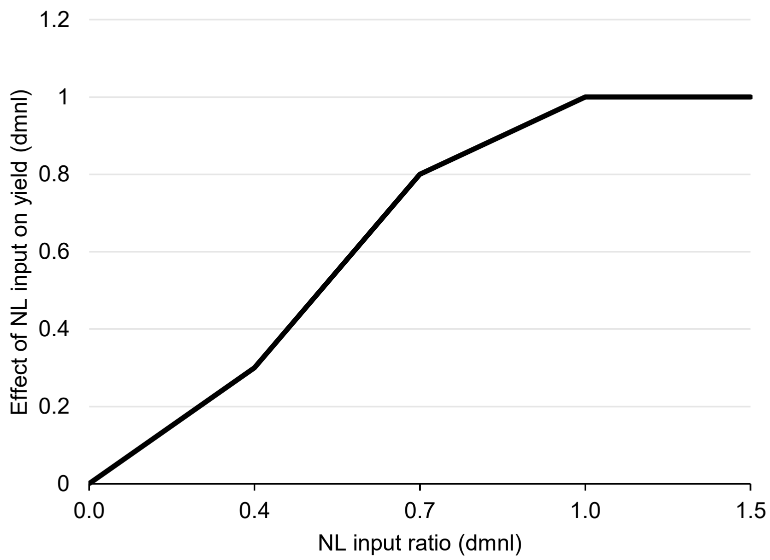
Based on *Indicated NL input* and *labour use* from yield profile, we have *NL input use ratio* and *Labour input use ratio* that are relative to indicated values which are dimensionless.

NL input use ratio = NL input use index per ha per crop/Indicated NL input use from yield profile [2.44]

Labour use ratio = Labour use per ha per crop/Indicated labour use from yield profile [2.45]

Input uses in turn have effects on *Paddy yield realized per ha per crop* that are already formulated earlier. These effects are estimated and assume to be similar for each type of input, as shown in Figure 2.17.

Figure 2.17 Effect of NL Input on Yield (dmnl)



NL input ratio (dmnl)	Effect of NL input on yield (dmnl)	Increment
0	0	
0.4	0.3	0.30
0.7	0.8	0.50
1.0	1.0	0.20
1.5	1.0	0.00

Source: Calibrated from the model

Now we continue to calculate financial-related variables, which also depend on *Cropping intensity*. *Farmer revenue per ha per year* is simply formulated as follow.

Farmer revenue per ha per year = (Paddy price + Subsidy per unit output sold)*Paddy sold per ha per crop*Cropping intensity + Transfer NL input subsidy [2.46]

Expected revenue per ha per year = SMOOTH (Farmer revenue per ha per year, Income average time) [2.47]

Variable annual cost composes of two components, namely *Labour cost per ha per crop* and *NL input cost per ha per crop* and calculated as follows. Note that subsidy on labour use is negligible, so is ignored in the formulation.

Labour cost per ha per crop = Unit labour cost*Labour use per ha per crop [2.48]

NL input cost per ha per crop = MAX (0,Unit NL cost per ha per crop-Subsidy on NL input) [2.49]

Expected labour cost per ha per crop = SMOOTH (Labour cost per ha per crop, Time to adjust expected cost) [2.50]

Expected NL input cost per ha per crop = SMOOTH (NL input cost per ha per crop, Time to adjust expected cost) [2.51]

Time to adjust expected cost = 1 [2.52]

Expected variable cost per ha per year = (Expected NL input cost per ha per crop + Expected labour cost per ha per crop)*Cropping intensity [2.53]

Based on these revenue and cost variables, *Expected profitability per ha per year (EP)* is derived as shown in equation 2.33

Finally, there are other exogenous variables used in the model, namely (i) *Unit labour cost*, (ii) *Unit NL cost*, and (iii) *Paddy price.* The two unit costs are supposed to increase over time with a small increase fraction: 2.1% per year for *NL cost* and 4.1% per year for *Labour cost*. Note that, based on FGDs, *Labour cost* increases at a higher rate than that of *NL cost*. On the other hand, *Paddy price* is assumed to increase at a fraction of 2% per year, which is estimated from paddy price data.

2.4 Model Testing

2.4.1 Reproduction of Reference Mode (1980 – 2015) vs Base-run (1980 – 2050)

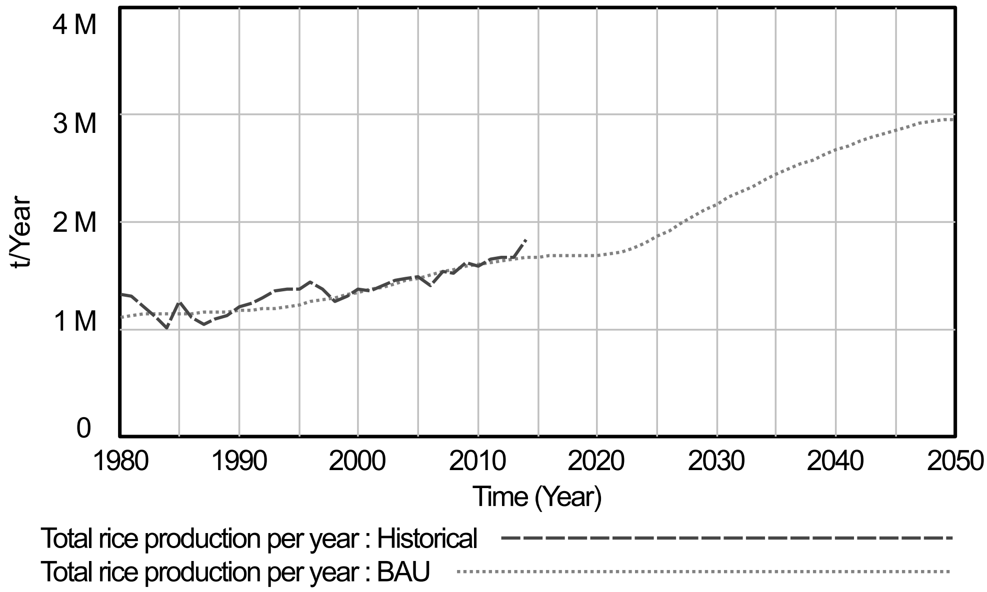
Initial values of key variables were estimated from the primary and secondary data collected from FGD and KII on major stakeholders, as well as published reports respectively as depicted in Table 2.2. Tests were also conducted to build up confidence in the model. Tests for building confidence in system dynamics models essentially consist of validation, sensitivity analysis and policy analysis. To build up confidence in the projections of the model, various ways of validating a model such as: validating the model structures, comparing the model estimates with historical data, ensuring the model generates plausible behaviour and checking the quality of the parameter values.

Figures 2.18 – 2.22 show the comparison between the projected and historical behaviour of *Total rice production per year, Rice requirement, SSL, Paddy yield realized per ha per crop* and *Paddy planted area*. The simulated food self-sufficiency ratio estimated by the model agrees reasonably well with the historical behaviour which suggests that the model is reliable. The validated model is used for base-run scenario and policy analysis.

Table 2.2 Data on Initial Values of Stock Variables, Constants and Parameters

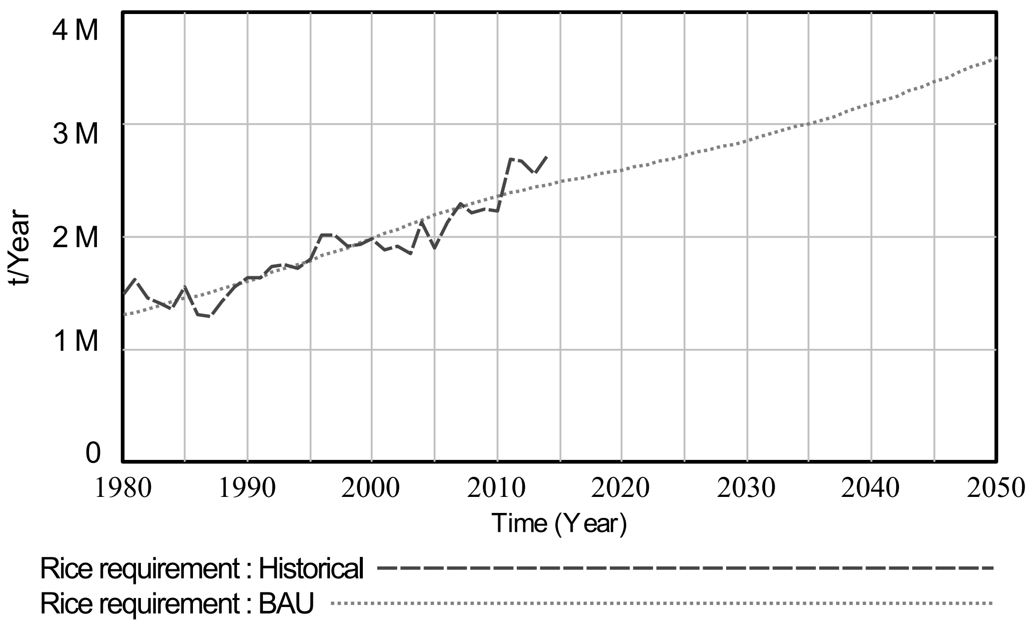
Variable Name	Initial Value	Units	Sources
Cropping intensity	1.6	crop/Year	Estimated from DOS (1980)
Labour use per ha per crop	35	Man-days/ha/crop	Estimated from Fatimah et. al (2019)
NL input use index per ha per crop	100	Index/ha/crop	Estimated from Ricepedia (2012)
Per capita consumption	0.094	t/People/ Year	Estimated from MOA (2017)
Physical paddy land	448,046	ha	DOS (2017a)
Population	13,879,000	people	DOS (2017b)
Unit NL cost after 2018	10.3	RM/index	Estimated from Ricepedia (2012)
Parameter			
Adjustment factor for production calculation	1.2	dmnl	Assumption
Adjustment time for potential yield per ha per crop	10	Year	Estimated from MARDI (2002)
AT for labour input	1	Year	Assumption
AT for NL input	1	Year	Assumption
AT for R&D	2	Year	Assumption
Income average time	1	Year	Assumption
Initial potential paddy yield per ha per crop	3	t/(ha*crop)	Tajuddin, S (2014)
Initial RnD capacity index	100	index	Assumption
Initial Unit Labour Cost	2.41	RM/man days	Estimated from Kalshoven (1984)
Normal effect of development local input on unit NL cost	1	dmnl	Assumption
Normal yield delay time	2	Year	Assumption
other factor production	0.9	dmnl	Assumption
Paddy deduction fraction	0.2	dmnl	Key informant survey
Paddy price BAU 2018	1,200	RM/t	MOA (2016)
Paddy price policy 2018	2,400	RM/t	Assumption
Paddy to rice conversion	0.65	dmnl	MOA (2016)
SSL Target	0.85	dmnl	PEMANDU (2010)
Time to adjust expected cost	1	Year	Assumption
Time to smooth SSL	2	Year	Assumption
Yield delay time after 2018	1	Year	Assumption

Figure 2.18 Simulated and Historical Data of Total Rice Production in Malaysia (t/year), 1980 – 2050



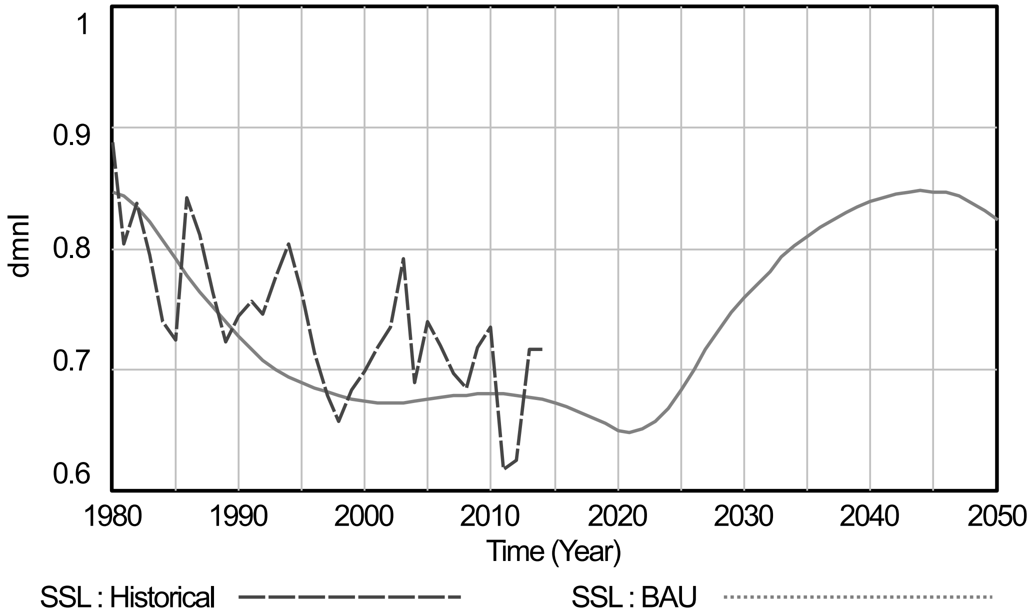
Source: Calibrated from the model. Historical data based on DOS (2017a)

Figure 2.19 Simulated and Historical Data of Rice Requirement in Malaysia (t/year), 1980 – 2050



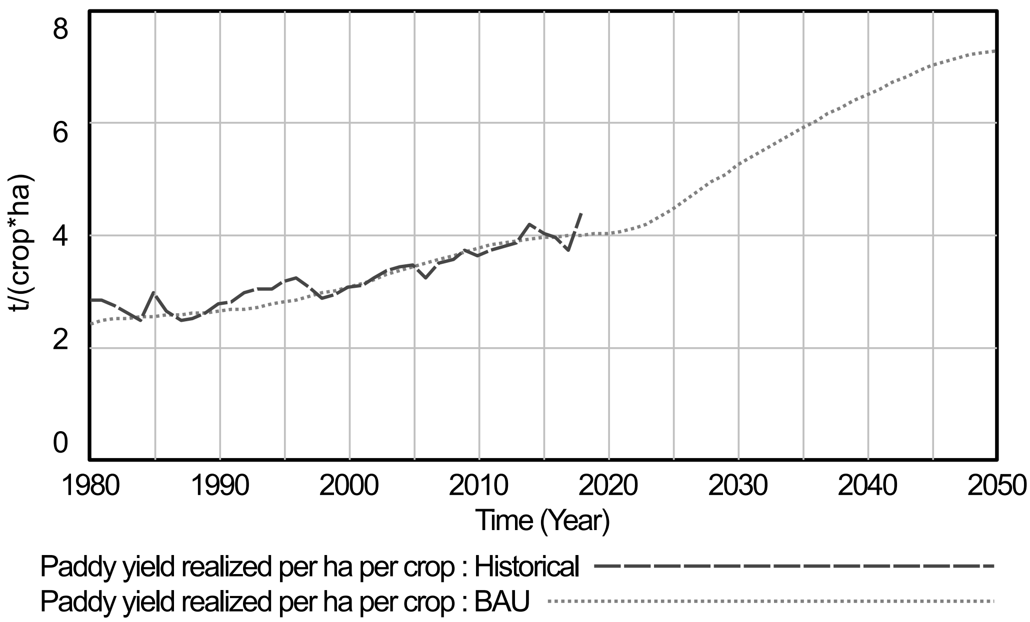
Source: Calibrated from the model. Historical data estimated based on DOS (2017b) and FAOSTAT (2017b)

Figure 2.20 Simulated and Historical Data of SSL in Malaysia (%), 1980 – 2050



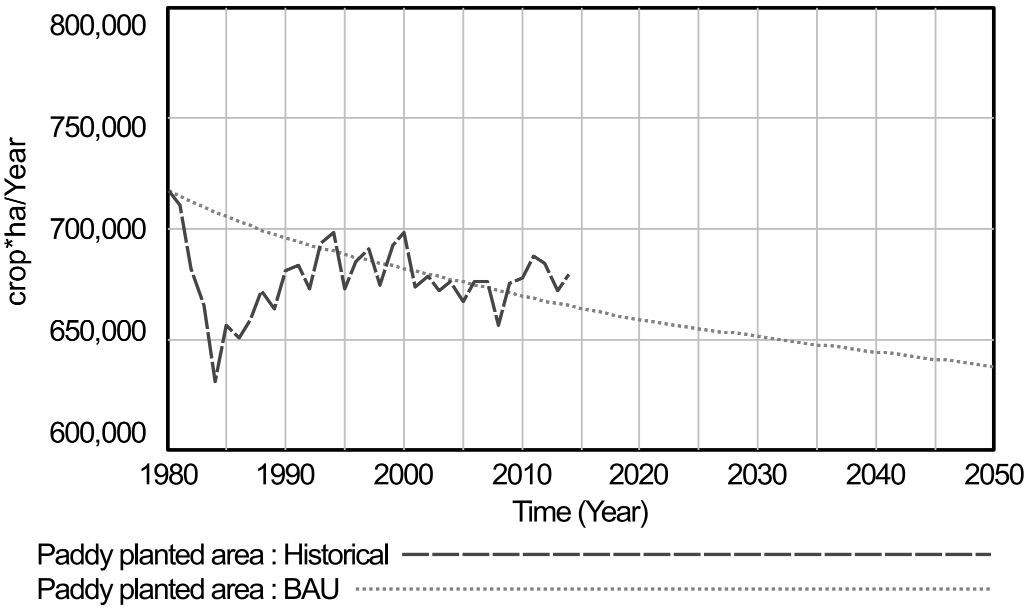
Source: Calibrated from the model. Historical data based on MOA (2017)

Figure 2.21 Simulated and Historical Data of Paddy Yield Realized per ha per crop in Malaysia (t/ha/crop), 1980 – 2050



Source: Calibrated from the model. Historical data based on DOS (2017a)

Figure 2.22 Simulated and Historical Data of Paddy Planted Area in Malaysia (ha), 1980 – 2050



Source: Calibrated from the model. Historical data based on DOS (2017a)

Theil's Inequality Statistics

Most system dynamics models are not designed to provide point forecasts but rather they are built to display the dynamic behavior of the system under consideration. However being able to fit historical data brings greater credibility to the model and a lot of effort is now put into behavior reproduction tests (Shepherd, 2014). Theil's inequality statistics provide a decomposition of the total error (mean square error) in the model into three parts: proportion due to bias or unequal mean (U^M), proportion due to unequal variations (U^S), and proportion due to unequal covariation (U^C) (Sterman, 2000). Note that a good fit is indicated by small values of U^M and U^S i.e. smaller differences in the mean and variation, respectively. Since their sum equals one, smaller U^M and U^S are associated with larger U^C.

Table 2.3 summarizes the error analysis for the six key variables considered in the model. Root Mean Square Percent Error (RMSPE) are below 10% for all variables, indicating the model behaviour is close to that shown by historical data. The lowest RMPSE is variable Total population (0.8%), indicates that the variable replicates the behavior accurately. Of this small magnitude error, the major portion (52%) is due to unequal variation and 46% is due to unequal covariation. The Rice requirement is characterized by an RMSPE of 8%, highest among the key variables selected. The error decomposition reveals that 96% of Mean Square Error (MSE) is due to unequal covariation and 3% due to unequal variation.

Table 2.3 Summary of Theil's Statistics, 1980 – 2014

Variables	RMS Percent Error (%)	Theil Inequality Statistics		
		U^m	U^s	U^c
Paddy Planted Area	3.7	0.18	0.00	0.82
Paddy Yield Realized per ha per crop	6.6	0.17	0.08	0.75
Rice Requirement	8.0	0.00	0.03	0.96
SSL	6.8	0.19	0.00	0.81
Total Population	0.8	0.02	0.52	0.46
Total Rice Production per year	7.2	0.15	0.01	0.84

Notes:

1. U^m is bias between means of model and actual data
2. U^s is difference between variation of model and actual data
3. U^c is unsystematic errors between model and actual data

Source: From model

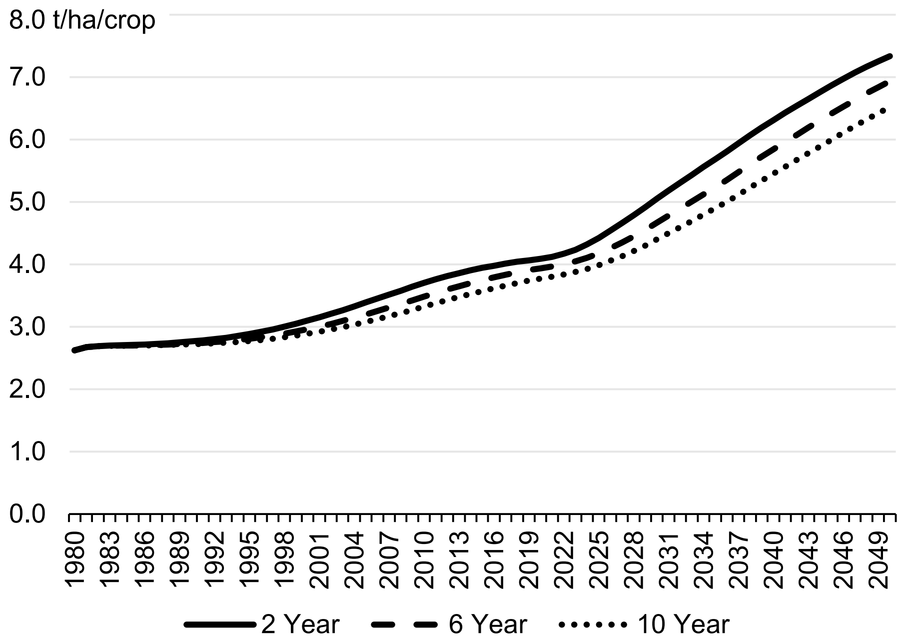
2.4.2 Sensitivity Analysis (To Test Sensitivity for Key Parameters and Table Functions)

No model can replicate perfectly the complexity of reality. However, we can test the robustness of the model's conclusion to uncertainty in the assumptions made. Sensitivity analysis is used to determine how "sensitive" a model is to changes in the value of the parameters of the model and to changes in the structure of the model. Sensitivity analysis also tests whether the conclusions change in ways that are relevant to the problems studied when assumptions are changed over the plausible range of uncertainty. This analysis is important for the following reasons. First, it helps develop our intuition regarding the relationship between the structure and behaviour of the dynamic systems under study. Second, it helps us to test the robustness of the conclusions with respect to uncertainty in the estimated parameters. Third, it guides us in data collection in that a parameter that strongly affects the behaviour may be a good indicator for additional data collection. Fourth, parameters that strongly affect the behaviour of the model may be high leverage points for policy intervention.

A parameter sensitivity is implemented to examine how a change in the parameter causes a change in the dynamic behaviour of the stocks. By showing how the model behaviour changes in response to change in parameter values, sensitivity analysis is a useful exercise in model building and evaluation. If one continues to see the same general pattern of behaviour in many different simulations, the model is said to be robust. The paddy model to some extent draws on partial information and judgemental estimation. It is certainly filled with uncertain parameters, hence it is important to learn if the model's tendency is robust.

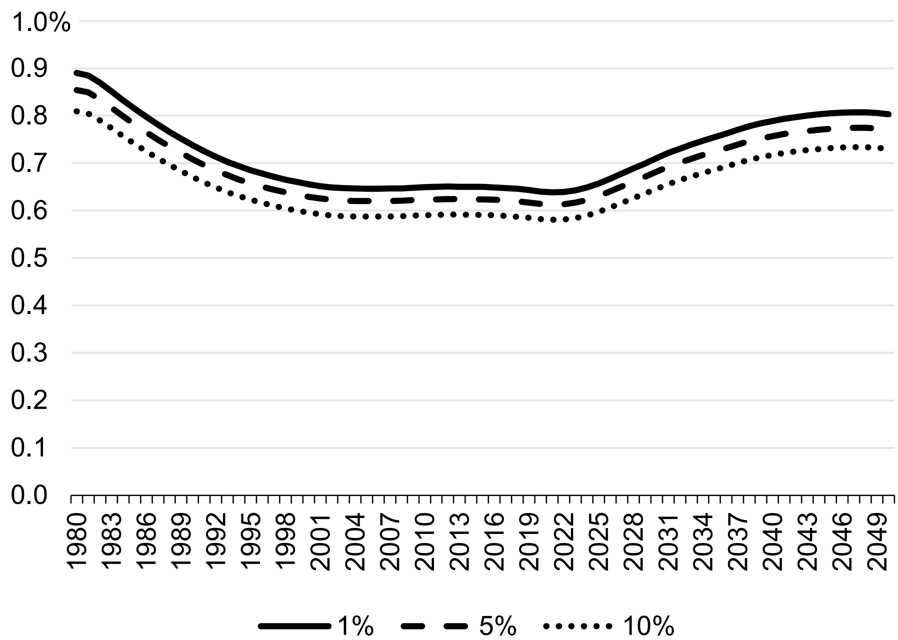
Figure 2.23 shows the first sensitivity test conducted. It shows how the yield growth pattern is altered by changes in the time to implement potential yield. The middle simulation line reflects the base case, with the implementation time of 6 years. The simulation line that indicates a Paddy yield realised per ha per crop about 8 t/ha/crop assumes the implementation time of 1 year. The lower simulation assumes the potential yield implementation time of 10 years. The three simulations are quite different when judged in terms of their peak Paddy yield realised per ha per crop. On the other hand, all simulations show the same tendency of the Paddy yield realised per ha per crop once the potential yield implement time is altered. Since our purpose is to understand the system's tendency, we would say the model is robust with respect to changes in this parameter.

Figure 2.23 Sensitivity of the Paddy Yield Realized per ha per crop to Changes in the Time to Implement Potential Yield (t/ha/crop), 1980 – 2050



Source: Authors, from model

Figure 2.24 Sensitivity of the SSL to Changes in the Paddy Post-Harvest Loss (%), 1980 – 2050

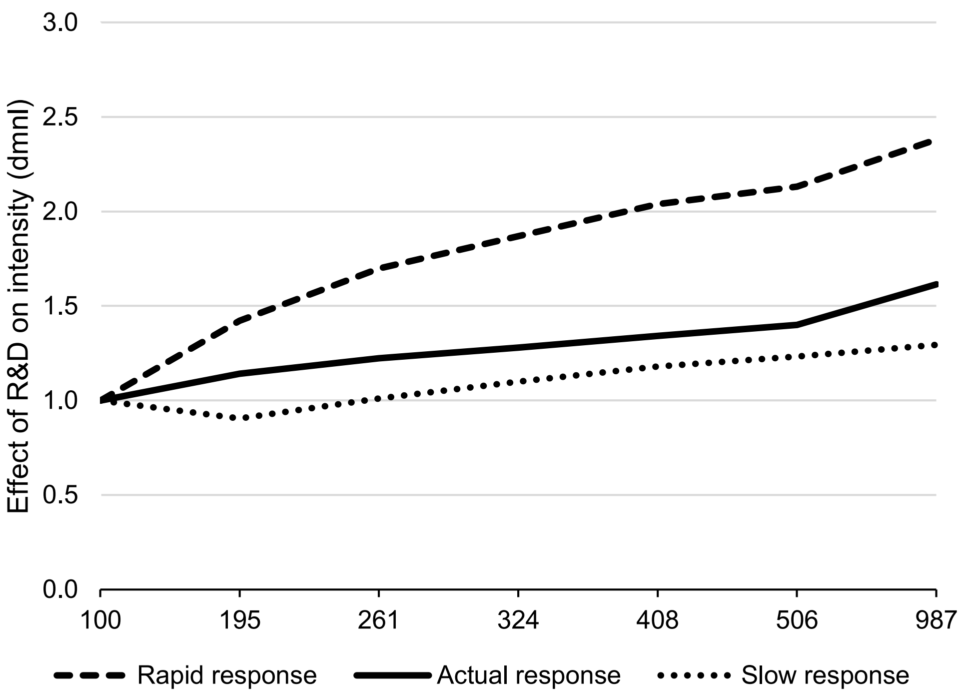


Source: Authors, from model

Figure 2.24 shows a second sensitivity test to observe the tendency of SSL under large changes in the value of the Paddy post-harvest losses from a low of 1% to a high of 10%. The test outcomes yield the same finding as in the previous test. The model shows the same general tendency despite large variations in these uncertain parameters.

The previous tests are easily implemented, because the changes are limited to one of the constants in the model. But it is also important to test the sensitivity of the model to changes in the nonlinear functions. Figure 2.25 illustrates how such tests are conducted and it portrays three possible assumptions for the nonlinear relationship between the *Effect of R&D on intensity* and the *Paddy planted area*. The three possible assumptions are rapid response, actual response and slow response. The middle graph is the base case assumption used previously. The top graph assumes that the *Effect of R&D on intensity* responds more rapidly to a decline in the *Paddy planted area*. And the lower graph assumes a slow response.

Figure 2.25 Three Possible Effects of the Expected of the R&D on Intensity to the Paddy Planted (dmnl)

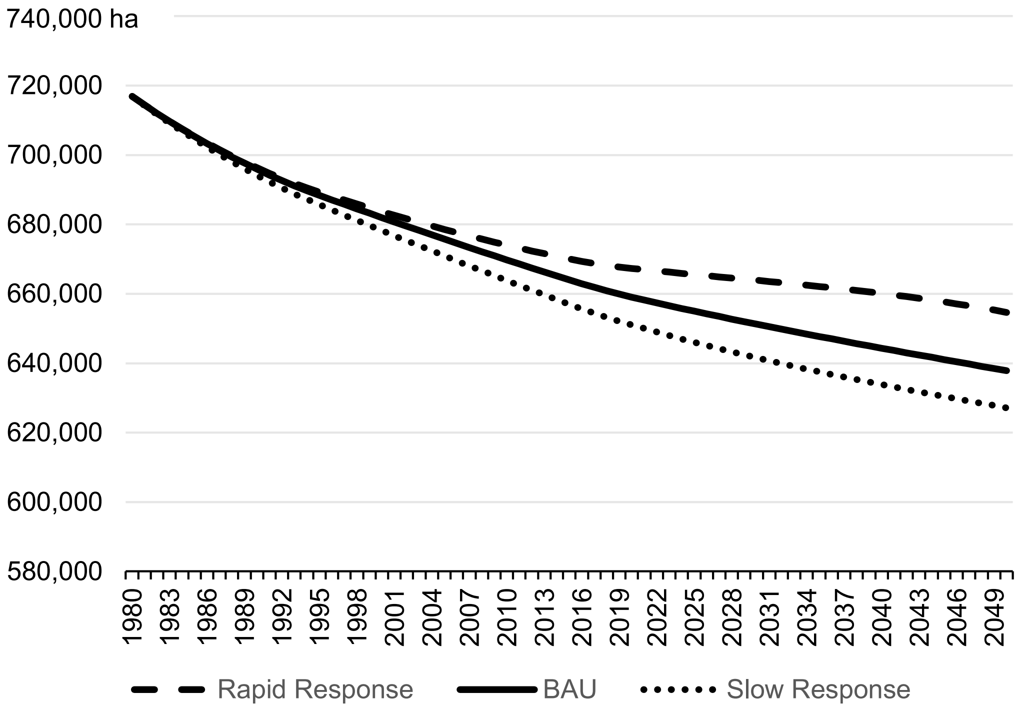


Source: Authors, from model

Figure 2.26 shows a comparison of the *Paddy planted area* with the three assumptions on this nonlinear relationship. The middle simulation is the same as the base case simulation shown previously. The first of the three simulations adopts the assumption that the Paddy *planted area* responds only slowly to changes in the *Effect of R&D on intensity*. If this was the case, the Paddy *planted area* would reach a value of 627,000 ha. The third simulation adopts the higher graph shown in Figure 2.26. This simulation assumes an earlier and stronger response of the *Effect of R&D on intensity* to changes in the *Paddy planted area*. With this third assumption, the *Effect of R&D on intensity* is simulated to hit a peak value of almost 655,000 (ha).

This combination of sensitivity tests confirms that the model's general tendencies are robust across wide variations in the numerical estimates of the uncertain parameters. It appears that the underlying structure of the paddy rice model is far more important than the numerical estimates of the model parameters. The model is deemed ready for policy simulations which are discussed in the following section.

Figure 2.26 Desired R&D in Simulations with Three Different Responses



Source: Authors, from model

3

POLICY DESIGN AND EVALUATION

3.1 Policy Simulation

For policy simulation purposes, this study examines the implications of changes in the subsidy, RDE strategies and input sector development. Preliminary attempts were made to simulate the impact of each of the policy instruments individually and identify which gives a significant impact on system performance. Based on these runs, the study has identified a number of policy combinations of three thematic areas namely:

(i) Subsidy restructuring;

(ii) RDE strategies comprising the intensification of paddy extension services, enhancing R&D capacity and related infrastructure to increase potential yield and cropping intensity; and

(iii) Development of local input sector. Under subsidy restructuring, a single policy simulation on the continuous increase in input subsidy is attempted individually to examine the implications if this policy is implemented. The policy scenarios considered are summarised in Table 3.1.

The policy mixes tested are as follows:

S1: Total transfer of input subsidy to output subsidy and RDE strategy to intensify extension services.

S2: Immediate withdrawal of the input subsidy and RDE strategy to improve yield.

S3: Continuous increase of input subsidy.

S4: Combination of intensification of paddy extension services, enhancing R&D capacity and related infrastructure to increase potential yield and cropping intensity.

S5: Combination of S4 and development of local input sector.

S6: Combination of S4 and S1 (total transfer of input subsidy to output subsidy).

S7: Combination of S4 and S2 (immediate withdrawal of the input subsidy).

Table 3.1 The List of Simulation Runs in the Model

Simulation	Subsidy restructuring			RDE strategy			Development of Local Input Sector
	Total transfer of input subsidy to output	Immediate withdrawal of input subsidy:	Continuous increase in input subsidy	Reduction in delay time	Yield improvement	Enhancing cropping intensity	
S1	X			X			
S2		X			X		
S3			X				
S4				X	X	X	
S5				X	X	X	X
S6	X			X	X	X	
S7		X		X	X	X	

Source: Authors

All the policy changes are assumed to start in 2018 and run until 2050. Each policy simulation results are compared to the base run or Business as Usual (BAU) values to assess its relative effectiveness. How it affects the sub-systems and their variables is also discussed. The list of adjustments made that reflect the new policy changes are listed in Table 3.2.

The selected impacted variables vary according to the simulation. However, the major indicator variables are: *Net revenue per ha per year, Expected variable cost per ha per year, Expected profitability per ha per year (EP), SSL* and *Total rice production per year.* A number of indicators are calculated to evaluate the impact of the simulation runs. They are:

(i) **POBR** or "Policy over base run" which represents the ratio of the simulated over the **base run** values of the variable concerned in the simulation year, in this case, 2050. A ratio greater than 1 implies an improvement while a ratio less than 1 indicates otherwise (depending on the context of the simulation).

(ii) **COBR%** or "% change over base run" is the translation of POBR in percentage term.

(iii) "**2018 – 2050 Absolute change**" represents the quantitative change in the value of the variable between 2050 (the year simulation ends) and the base year (2018). This figure is translated into percentage term called "% change over base year" or **PCOB.**

To facilitate the simulation exercises of the stock and flow diagram in the Vensim platform, a number of switches were provided for easier manouvering. That is, to activate a simulation, one has to turn on the relevant switch (es) and vice versa.

Table 3.2 Policy Scenarios and Adjustments Made on the Model

<table>
<tr><th>Scenario and Policy Variable</th><th>Brief Description</th></tr>
<tr><td>Baseline</td><td>A “business as usual” or BAU scenario</td></tr>
<tr><td colspan="2">Policy Change Related to Subsidy</td></tr>
<tr><td>S1. Total transfer of input subsidy to output subsidy and RDE strategy to intensify extension services</td><td>The input subsidy is transferred to the output subsidy and yield delay time for extension is shortened..

Variables changed: “Subsidy on NL input” and “Transfer NL input subsidy” and “Yield delay time”

Changes in equations:
<table>
<tr><td>Before policy change
Subsidy on NL input = ((45+ STEP(213, 1990)+STEP(672.5,2008)))

Transfer NL input subsidy = 0

Yield delay time = Normal yield delay time</td><td>After policy change
Subsidy on NL input = ((45+STEP(213,1990)+STEP(672.5,2008)))-STEP(930.5,2018)

Transfer NL input subsidy = IF THEN ELSE(Subsidy on NL input>0,0,IF THEN ELSE (Time<2018, 0, 930.5*Cropping intensity))

Yield delay time after 2018 = 1</td></tr>
</table></td></tr>
<tr><td>S2. Immediate withdrawal of input subsidy and RDE strategy to improve yield</td><td>This run examines the impact of immediate withdrawal of input subsidy in 2018 and R&D strategy to improve yield.

Variable changed: “Subsidy on NL input” and “Indicated potential yield per ha per crop”

Changes in equation:
<table>
<tr><td>Before policy change
Subsidy on NL input = ((45+STEP (213,1990)+STEP(672.5,2008)))-STEP(930.5,2018)*0

Indicated potential yield per ha per crop = Effect of R&D on yield improvement

"Effect of R&D on yield improvement"= WITH LOOKUP ("R&D capacity index",([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.2),(400,2.7),(500,3)))</td><td>After policy change
Subsidy on NL input = ((45+STEP (213,1990)+STEP(672.5,2008)))-STEP(930.5,2018)*1

Indicated potential yield per ha per crop = Effect of R&D on yield improvement policy

"Effect of R&D on yield improvement policy"= WITH LOOKUP ("R&D capacity index", ([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.5),(400,3),(500,3.2)))</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario and Policy Variable</th><th>Brief Description</th></tr>
<tr><td>S3. Continuous increase in input subsidy</td><td>This run examines the impact of a continuous increase in input subsidy by RM50/year.

Variable changed: “Subsidy on NL input”

Changes in equation:
<table>
<tr><td>Before policy change
Subsidy on NL input = ((45+STEP (213,1990)+STEP(672.5,2008))) +RAMP(50, 2018, 2050)*0</td><td>After policy change
Subsidy on NL input = ((45+STEP (213,1990)+STEP(672.5,2008))) +RAMP(50, 2018, 2050)*1</td></tr>
</table></td></tr>
<tr><td>S4. RDE strategies to improve extension, yield and cropping intensity</td><td>S4 tests the mix of RDE strategies comprises:
Intensification of paddy extension services intensification through shorter delay time in implementing high yield,
Enhancing R&D capacity to increase potential yield,
Enhancing R&D capacity and related infrastructure to increase cropping intensity.

Variable changed are: “Yield delay time”, “Indicated potential yield per ha per crop”, “Effect of R&D on yield improvement policy” and “Effect of R&D on intensity Policy”

Changes in equations:
<table>
<tr><td>Before policy change
Yield delay time = Normal yield delay time

Indicated potential yield per ha per crop = Effect of R&D on yield improvement

Effect of R&D on yield improvement = WITH LOOKUP (R&D capacity index,([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.2),(400,2.7),(500,3)))

Effect of R&D on intensity = WITH LOOKUP ("R&D capacity index",([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.27895),(395.538,1.34211),(500.941,1.4),(991.743,1.61404)))

Intensity growth fraction table (moderate)([(1980,0)-(2050,0.002)],(1980,0.0015),(2020,0.0015),(2050,0))</td><td>After policy change
Yield delay time after 2018 = 1

Indicated potential yield per ha per crop = Effect of R&D on yield improvement policy

Effect of R&D on yield improvement policy = WITH LOOKUP (R&D capacity index, ([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.5),(400,3),(500,3.2)))

Effect of R&D on intensity policy = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.8),(391.878,1.94737),(495.535,1.98246),(991.743,2)))

Intensity growth fraction table (optimistic condition)([(1980,0)-(2050,0.005)],(1980,0.0015),(2020,0.0015),(2030,0.0015),(2050,0.004))</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario and Policy Variable</th><th>Brief Description</th></tr>
<tr><td>S5. Combination of S4 and development of local input sector</td><td>S5 tests the combination of S4 and development of local input sector.

Variable changed are: “Yield delay time”, “Indicated potential yield per ha per crop”, “Effect of R&D on yield improvement policy”, “Effect of R&D on intensity Policy” and “Unit NL cost after 2018 change rate”

Additional new structure on the development input index added to the current stock and flow diagram in Figure 2.9. The new structure is discussed under Section 3.1.6.

Changes in equations:
<table>
<tr><td>Before policy change
Yield delay time = Normal yield delay time

Indicated potential yield per ha per crop = Effect of R&D on yield improvement

Effect of R&D on yield improvement = WITH LOOKUP (R&D capacity index,([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.2),(400,2.7),(500,3)))

Effect of R&D on intensity = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.27895),(395.538,1.34211),(500.941,1.4),(991.743,1.61404)))

Intensity growth fraction table (moderate)([(1980,0)-(2050,0.002)],(1980,0.0015),(2020,0.0015),(2050,0))

Unit NL cost after 2018 change rate = Normal effect of development local input on unit NL cost</td>
<td>After policy change
Yield delay time after 2018 = 1

Indicated potential yield per ha per crop = Effect of R&D on yield improvement policy

Effect of R&D on yield improvement policy = WITH LOOKUP ("R&D capacity index",([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.5),(400,3),(500,3.2)))

Effect of R&D on intensity policy = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.8),(391.878,1.94737),(495.535,1.98246),(991.743,2)))

Intensity growth fraction table (optimistic condition)([(1980,0)-(2050,0.005)],(1980,0.0015),(2020,0.0015),(2030,0.0015),(2050,0.004))

Unit NL cost after 2018 change rate = Unit NL cost after 2018* Unit NL cost fractional change after 2018* Effect of development local input on unit NL cost* Normal effect of development local input on unit NL cost</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Scenario and Policy Variable</th><th>Brief Description</th></tr>
<tr><td>S6. Combination of S4 and S1(total transfer of input subsidy to output subsidy)</td><td>
S6 tests the combination of S4 and S1 which is restructuring from input to output sector

Variables changed:
As in S4 with addition of “Subsidy on NL input” and “Transfer NL input subsidy”.

Changes in equations:
<table>
<tr><th>Before policy change</th><th>After policy change</th></tr>
<tr><td>Yield delay time = Normal yield delay time</td><td>Yield delay time after 2018 = 1</td></tr>
<tr><td>Indicated potential yield per ha per crop = Effect of R&D on yield improvement</td><td>Indicated potential yield per ha per crop = Effect of R&D on yield improvement policy</td></tr>
<tr><td>Effect of R&D on yield improvement = WITH LOOKUP (R&D capacity index,([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.2),(400,2.7),(500,3)))</td><td>Effect of R&D on yield improvement policy = WITH LOOKUP (R&D capacity index, ([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.5),(400,3),(500,3.2)))</td></tr>
<tr><td>Effect of R&D on intensity = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.27895),(395.538,1.34211),(500.941,1.4),(991.743,1.61404)))</td><td>Effect of R&D on intensity policy = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.8),(391.878,1.94737),(495.535,1.98246),(991.743,2)))</td></tr>
<tr><td>Intensity growth fraction table (moderate)([(1980,0)-(2050,0.002)],(1980,0.0015),(2020,0.0015),(2050,0))</td><td>Intensity growth fraction table (optimistic condition)([(1980,0)-(2050,0.005)],(1980,0.0015),(2020,0.0015),(2030,0.0015),(2050,0.004))</td></tr>
<tr><td>Subsidy on NL input = ((45+STEP(213,1990)+STEP(672.5,2008)))</td><td>Subsidy on NL input = ((45+STEP(213,1990)+STEP(672.5,2008)))-STEP(930.5,2018)</td></tr>
<tr><td>Transfer NL input subsidy = 0</td><td>Transfer NL input subsidy = IF THEN ELSE(Subsidy on NL input>0,0,IF THEN ELSE(Time<2018, 0, 930.5*Cropping intensity))</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Scenario and Policy Variable</th><th>Brief Description</th></tr>
<tr><td>S7. Combination of S4 and S2 (immediate withdrawal of the input subsidy)</td><td>S7 tests the combination of S4 and S2 which is immediate withdrawal of input subsidy

Variables changed:
As in S4 and “Subsidy on NL input”

Changes in equations:
<table>
<tr><td>Before policy change
Yield delay time = Normal yield delay time

Indicated potential yield per ha per crop = Effect of R&D on yield improvement

Effect of R&D on yield improvement" = WITH LOOKUP ("R&D capacity index,([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.2),(400,2.7),(500,3)))

Effect of R&D on intensity = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.27895),(395.538,1.34211),(500.941,1.4),(991.743,1.61404)))

Intensity growth fraction table (moderate)([(1980,0)-(2050,0.002)],(1980,0.0015),(2020,0.0015),(2050,0))

Subsidy on NL input = ((45+STEP(213,1990)+STEP(672.5,2008)))-STEP(930.5,2018)*0</td>
<td>After policy change
Yield delay time after 2018 = 1

Indicated potential yield per ha per crop = Effect of R&D on yield improvement policy

Effect of R&D on yield improvement policy = WITH LOOKUP (R&D capacity index, ([(100,0)-(500,4)],(100,1),(125,1.1),(150,1.3),(175,1.5),(200,1.6),(250,1.6),(260,1.6),(300,2.5),(400,3),(500,3.2)))

Effect of R&D on intensity policy = WITH LOOKUP (R&D capacity index,([(100,0)-(992,2)],(100,1),(193.199,1.14211),(260,1.224),(301.882,1.8),(391.878,1.94737),(495.535,1.98246),(991.743,2)))

Intensity growth fraction table (optimistic condition)([(1980,0)-(2050,0.005)],(1980,0.0015),(2020,0.0015),(2030,0.0015),(2050,0.004))

Subsidy on NL input = ((45+STEP(213,1990)+STEP(672.5,2008)))-STEP(930.5,2018)*1</td></tr>
</table></td></tr>
</table>

Source: Authors, from model

3.2 Simulation Results

This section provides the results of the simulations for the various policy alternatives listed in Table 3.1. The selected impact variables vary with simulations. The selection is based on the sensitivity of the variables in responding to the policy changes. The impact is evaluated by POBR ratio, COBR% and PCOB explained earlier.

3.2.1 S1: Total Transfer of Input Subsidy to Output Subsidy and RDE Strategy to Intensify Extension Services

S1 explores the possible impact of this policy mix: the transfer of input subsidy to the output sector and RDE strategy to improve extension. This means that all the input subsidies are transferred to the *Farmer revenue per ha per year*. The latter is a combination of the GMP (RM1,200/t and SSHP of RM300/t). The delay time of extension is improved by the reduction of the current level from two to one year.

The immediate impact of this transfer is on the *Farmer revenue per ha per year* in the Farm: Revenue sub-system. As shown in Figure 2.10, farmer revenue determines the expected profitability which influences his decision on the input use (labour and NL input). The relationship of these two variables is determined by using a look-up tables. The relevant look-up tables are: *Effect of EP (Expected profitability per ha per crop) on desired input use* (NL input) and *Effect of OP on labour use.* The use of these two inputs affect paddy yield and variable cost.

Besides input, yield is affected by the delay time of transferring potential paddy yield to the farm. Under this simulation, the shortening of the delay in extension times improves yield. Higher yield leads improvement in production and SSL in the RDE sub-system.

On the other hand, variable cost affects the calculation of expected profitability and the consequent decision of input use in the Farm: Revenue and Input sub-systems respectively. These sub-systems are connected with the RDE sub-systems through paddy yield.

The combined effects of this simulation are shown in Table 3.3 and Figure 3.1. The immediate impact of the transfer of input subsidy to output is to increase the farmer's revenue which is reflected as *Farmer revenue* and *Expected revenue per ha per year* variables. Despite the increase in the revenue, the simulated *Expected profitability per ha per year (EP)* which is basically a mark-up ratio[78] shows a sharp decline after 2018 and later plateauing as shown in Figure 3.1(b). Under the BAU situation, the *Expected profitability per ha per year (EP)* reduces from 3.6 (2018) to 1.6 (2050) but under this simulation it reduces to 1.5. The POBR ratio is 0.9 indicating the simulated value in 2050 is 6.9% lower than the base run value. The expected profitability is declining due the increase in the *Expected variable cost per ha per year* as input subsidy is transferred to the output.

78 *Expected profitability per ha per year* is calculated as (*Expected revenue per ha per year-Expected variable cost per ha per year*)/*Expected variable cost per ha per year* (Figure 2.10).

The withdrawal of input subsidy means that the producer has to personally incur the expenses on input (both labour and non-labour) which leads to an increase in the *Expected variable cost per ha per year*. As shown in Table 3.3 and Figure 3.1(c), the POBR ratio is 1.09 which implies the *Expected Variable cost per ha per year* in 2050 is 9.5% higher than the BAU's figure. The simulated value stands at RM18,889 compared to base run value of RM17,260. The *Expected Variable cost per ha per year* increases by more than eight times between 2018 under BAU and more than nine times under this simulation.

The net revenue to farmers is the difference between the *Expected revenue per ha per year* and *Expected variable cost per ha per year*. Based on this formula, the simulated value of the *Net revenue per ha per year* in 2050 is RM28,689 while it is RM28,141 under BAU run. The POBR ratio is 1.02 indicating the simulated value is about 1.9% higher than the BAU.

The shortening of the delay time improves the *Paddy yield realised per ha per crop* by 83.5% that is from 4 to 7.3 t/ha/crop between 2018 and 2050 under BAU, while under the simulation it increases to 7.4 t/ha/crop, an increase of 81.5%. In 2050, the simulated yield is 1.1% higher than the BAU's figure indicated by the POBR ratio of 1.01.

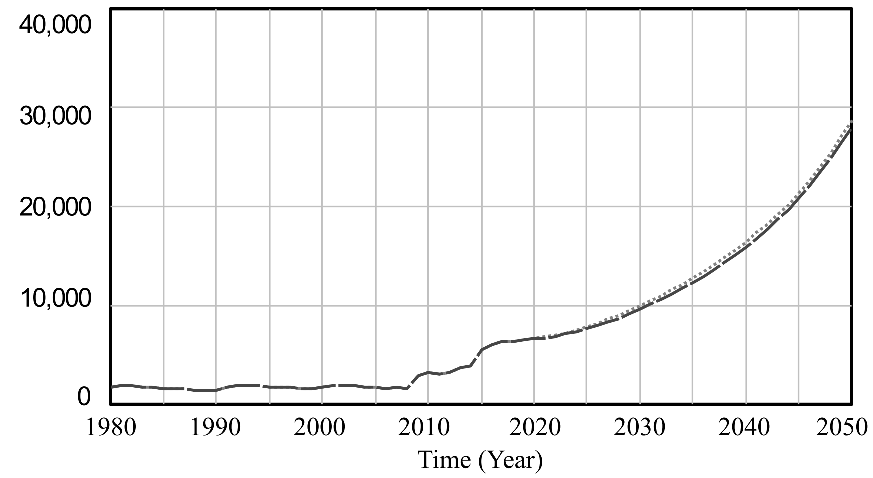
A similar percentage increase is shown for the *Total rice production per year* as it is derived by multiplying *Paddy planted area* and yield. In 2050 the simulated *Total rice production per year* reaches 3m t/year while it is 2.9m t/year under BAU with a POBR of 1.01. Over time the production increases by 75.2% from 1.7m t/year (2018) to 2.9m t/year (2050) under BAU while it increases by 77.1% to 3m t/year under this simulation.

Likewise, the improvement in SSL is very small too i.e., it increases by 25.7% under the simulation (2018 and 2050) compared to 24.4% under the BAU. By 2050, the SSL level achieved under simulation is 82% compared to 81% under BAU.

In conclusion, this combination does increase the farmers' revenue, yield, production and SSL, but by a very minimal amount. This indicates that this combination is still inadequate to trigger significant improvement in the said variables. Hence, there is a need to expand the mix to include other policy variables which are carried out in the following simulations.

Figure 3.1 S1: Combination of Total Transfer of Input Subsidy to Output Subsidy and RDE Strategy to Intensify Extension Services, 1980 – 2050

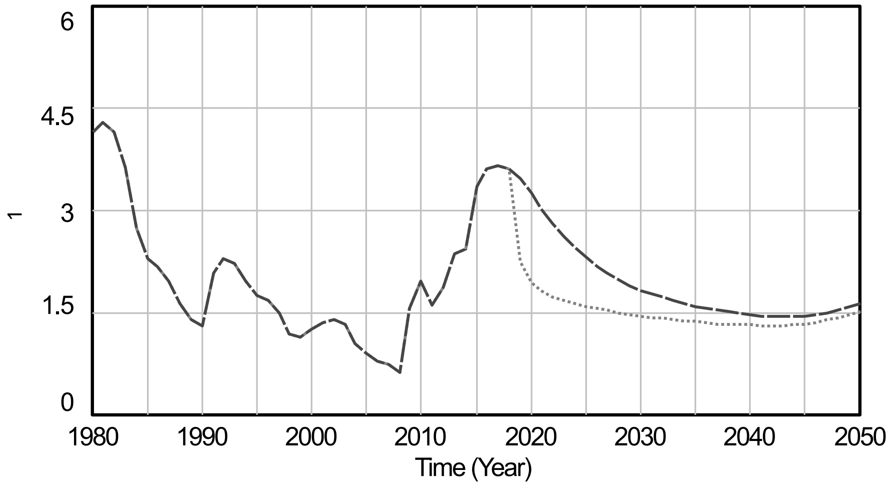
(a) Net revenue per ha per year



Net revenue per ha per year : BAU

Net revenue per ha per year : S1

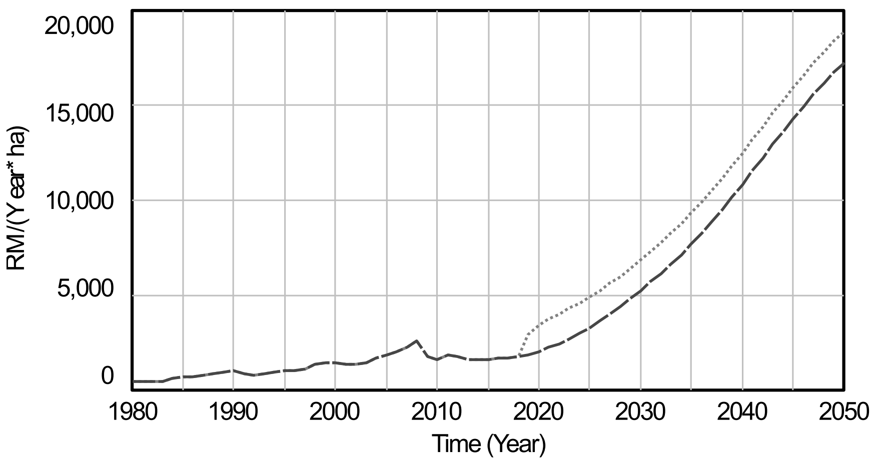
(b) Expected profitability per ha per year (EP)



"Expected profitability per ha per year (EP)" : BAU

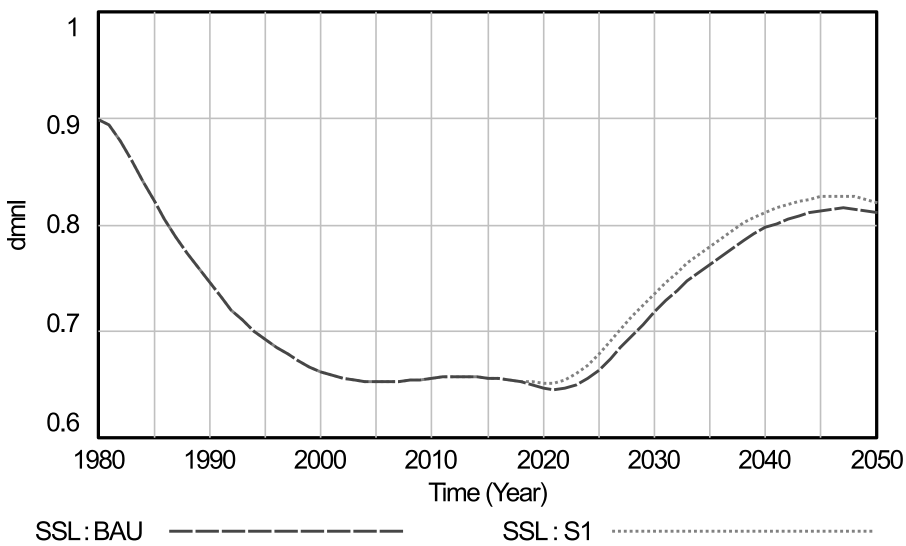
"Expected profitability per ha per year (EP)" : S1

(c) Expected variable cost per ha per year

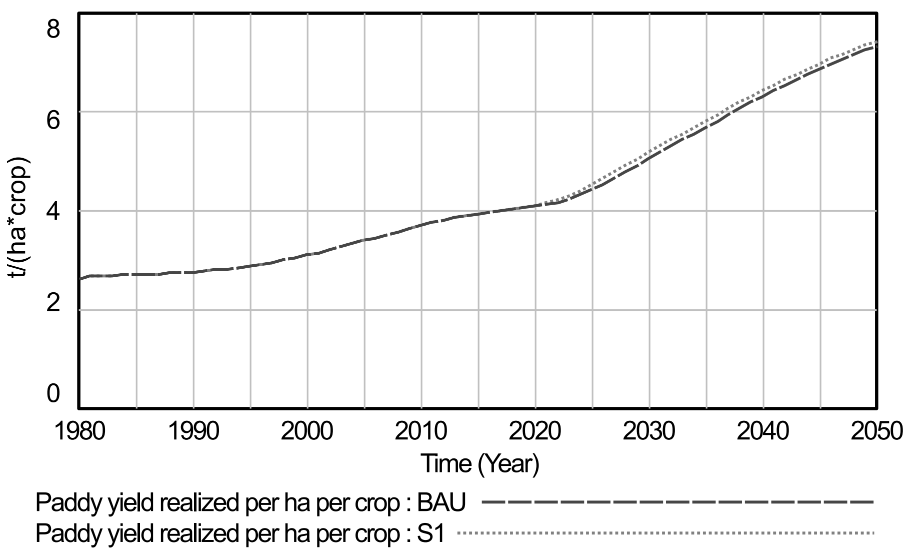


Expected variable cost per ha per year : BAU

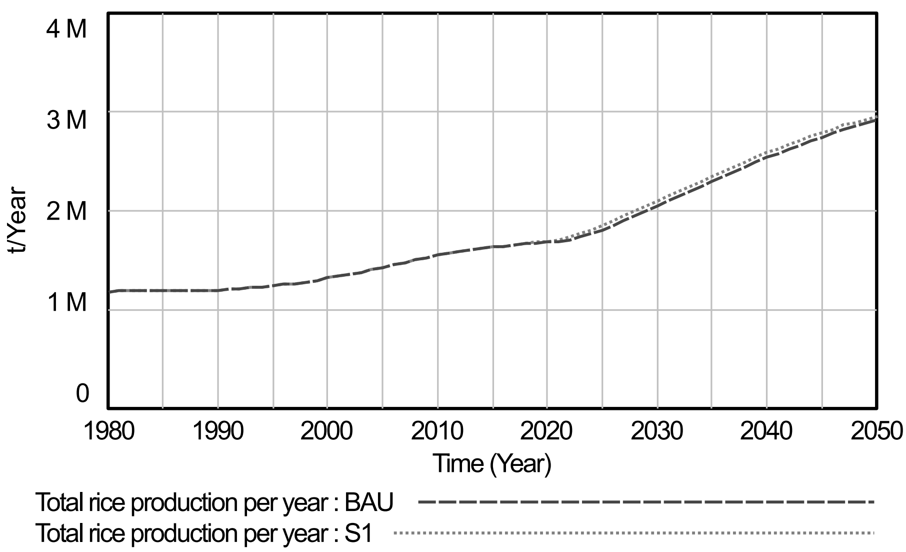
Expected variable cost per ha per year : S1 *(d) SSL*



(e) Paddy yield realized per ha per crop



(f) Total rice production per year



Source: Authors, from model

Table 3.3 S1: Combination of Total Transfer of Input Subsidy to Output Subsidy and RDE Strategy to Intensify Extension Services

Variable	Base run	S1
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	28,689
POBR		1.02
COBR%		1.9
2018-2050 Absolute change	21,768	22,316
PCOB	341.5	350.1
b) Expected Profitability per ha per year (Ratio)		
1980 (Initial year)	4.1	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.6	1.5
POBR		0.93
COBR%		-6.9
2018-2050 Absolute change	-2.0	-2.1
PCOB	-54.7	-57.8
c) Expected Variable Cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-
2018 (Beginning of change)	1,770	1,770
COBR%		0
2050 (Simulation ends)	17,260	18,899
POBR		1.09
COBR%		9.5
2018-2050 Absolute change	15,490	17,129
PCOB	875.1	967.7
d) SSL (%)		
1980 (Initial year)	0.90	-
2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.82
POBR		1.01
COBR%		1.1
2018-2050 Absolute change	0	0
PCOB	24.4	25.7

e) Paddy yield realized per ha per crop (t/ha/crop)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	7.4
POBR		1.01
COBR%		1.1
2018-2050 Absolute change	3.3	3.4
PCOB	81.5	83.5
f) Total rice production per year (t/year)		
1980 (Initial year)	1,172,929	-
2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0
2050 (Simulation ends)	2,918,697	2,950,933
POBR		1.01
COBR%		1.1
2018-2050 Absolute change	1,252,409	1,284,644
PCOB	75.2	77.1

Notes: POBR is Policy over base run, COBR% is Percentage change over base run, and PCOB is Percentage change over base year
Source: Authors, from model

The key takeaways of this simulation (S1) are:

- This policy simulates the combination of the transfer of input subsidies to output and improvement in extension.
- It results in a significant increase in the *Expected variable cost per ha per year* by one-tenth compared to the BAU figure, but marginal increase in producers' *Net revenue per ha per year* by 2%, while *Paddy yield realised per ha per crop, Total rice production per year* and *SSL,* each by 1%.
- The marginal increase is due to the dominance of the R&D and crop intensity and R&D for yield growth loops. That is, the slow growth in cropping intensity and paddy yield hinder further increase in rice production, SSL and net revenue.

3.2.2 S2: Immediate Withdrawal of Input Subsidy and RDE Strategy to Improve Yield

S2 explores the possible impact of the combination of immediate withdrawal of non-labour input subsidy and enhancing R&D capacity strategies to increase yield. Note that the output subsidy remains unchanged. Table 3.2 and Figure 3.2(d) show the immediate deactivation of the subsidy in 2018.

Despite the subsidy withdrawal, it is assumed that producers continue to farm and bear the cost of NL input themselves to maintain their livelihood[79]. In terms of lines of causality, the withdrawal of *Subsidy on NL input* directly affects input use and profitability in the Farm: Input and Revenue sub-systems respectively.

Since the producers bear the NL inputs for their farms, the variable cost increases by the amount spent. This is reflected in the increase of *Expected variable cost per ha per year* which resides in the Farm: Input sub-system. The increase in cost affects the *Expected profitability per ha per year (EP)* (or mark-up) which determines the input use (labour and NL input). As mentioned in S1, input use determines the paddy yield, rice production and SSL. Note also that the rice production determines the paddy sold by farmers and hence met revenue in the Farm: Revenue sub-system.

The yield increase is achieved by enhancing the *Effect of R&D on yield improvement* which in turn increases *Indicated potential yield per ha per crop* and *Potential paddy yield per ha per crop stock.* All these variables are located in the R&D for yield growth loop.

Improvement in the *Potential paddy yield per ha per crop* is followed by an increase in the *Paddy yield realised per ha per crop* at the farm, *Total rice production per year* and *SSL* in the RDE sub-system. Note also that *Total rice production per year* is an important variable in determining producers' profitability in the Farm: Input system as well as producers' revenue in the Farm: Revenue sub-system.

Under this run, the *Expected variable cost per ha per year* increases by ten times between 2018 and 2050 compared to nine times under the BAU run. The simulated value in 2050 is estimated at RM19,313/ha/year while under BAU run it is RM17,260/ha/year, a difference of 11.9% (with POBR ratio of 1.12).

The increase in *Expected variable cost per ha per year* affects the *Expected profitability per ha per year (EP).* As shown in Figure 3.2(b), its behaviour is similar as under S1. That is, immediate withdrawal causes profit to plunge in the short term. However, increases in *Net revenue per ha per year* due to higher *Total rice production per year*, causes it to pick up slowly after the earlier vertical dip.

The increase in *Total rice production per year* is due to the increase in *Paddy yield realised per ha per crop.* As shown in Figure 3.2(h), enhancing the R&D in yield improvement causes the *Potential paddy yield per ha per crop* to increase from 4.6 t/ha/crop in the base year to 9 t/ha per crop in 2050, an increase of 97.1%. Under the BAU it increases from 4.6 to 8.3 t/ha/crop, an increase of 82.6%. The POBR ratio is 1.08 which means the simulated value is 8% above the base run value in 2050.

79 Based on findings of focus group discussion (Appendix 3) as well as Riggs *et al.* (2016).

The increase in R&D effort to improve yield causes the *Paddy yield realized per ha per crop* at the farm doubles from 4 to 8 t/ha/crop in 2050 while under the BAU run it increases to 7.3 t/ha/crop. The POBR ratio is 1.08 indicating the simulated value is about 8.4% higher than the value achieved under BAU.

An increase in *Paddy yield realized per ha per crop* pushes the *Total rice production per year* higher by 89.8% from 1.7m t/year to 3.2m t/year (2018 – 2050). Under BAU, it only increases by three-quarter from 1.7m t/year to 2.9m t/year. The POBR ratio is 1.08 indicating the simulated value is 8.4% more than the BAU run.

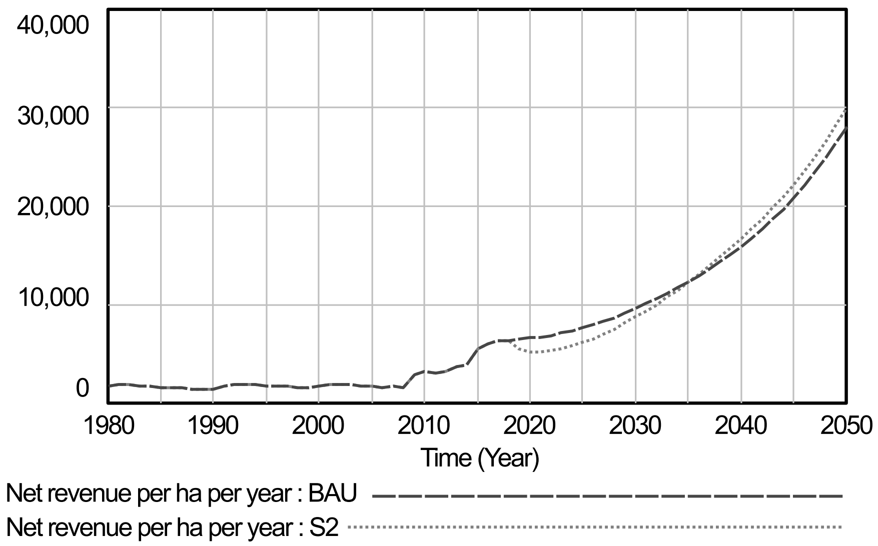
The *SSL* improves by more than a third under the new run from 65% in the base year to 88% in 2050 compared to an increase by a quarter, from 65% to 81% under BAU. The POBR ratio of 1.08 indicates the simulated value is 8.4% higher than the BAU run. However, the *SSL* curves tend to decline in the mid-2040s and beyond. This is because of the pull from higher increase in rice requirement (due to population rise) relative to production which affects the SSL ratio.

The *Net revenue per ha per year* increases 3.7 times from RM6,474 in the base year to RM29,965 in 2050. Under BAU, it increases by 3.4 times to RM21,768. Note that during the first 10 years of simulation period, the simulated net revenue is below the BAU figure after which it begins to increase above the BAU line. This behaviour is expected as the realisation of RDE effects take time.

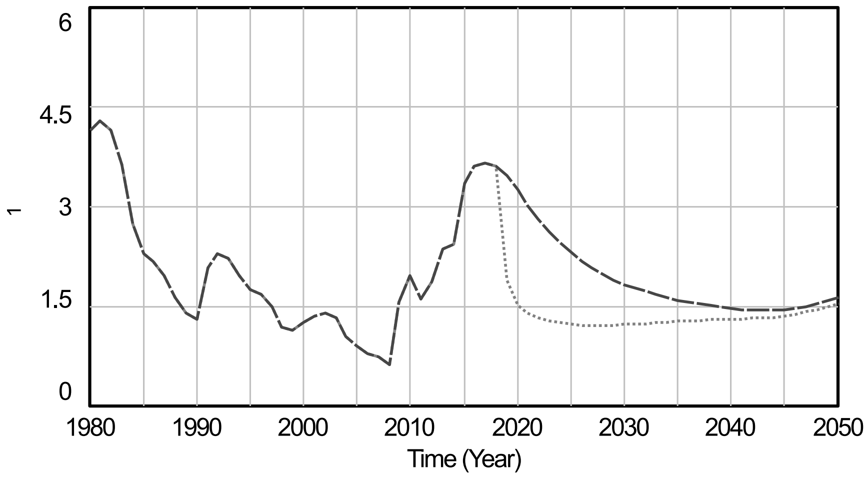
In conclusion, the loss from the withdrawal of input subsidy is compensated by the policy of enhancing yield and it proves to be more profitable albeit at a lower extent compared to S1.

Figure 3.2 S2: Combination of Immediate Withdrawal of Input Subsidy and Strategy to Improve Yield, 1980 – 2050

(a) Net revenue per ha per year

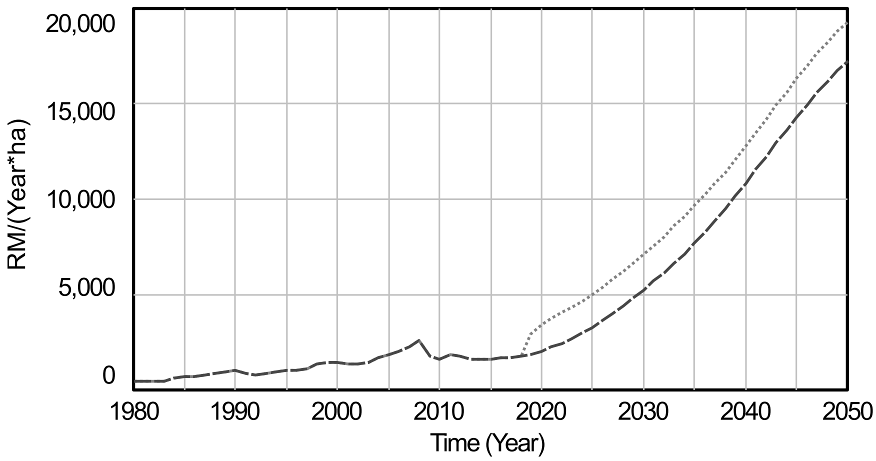


(b) Expected profitability per ha per year (EP)



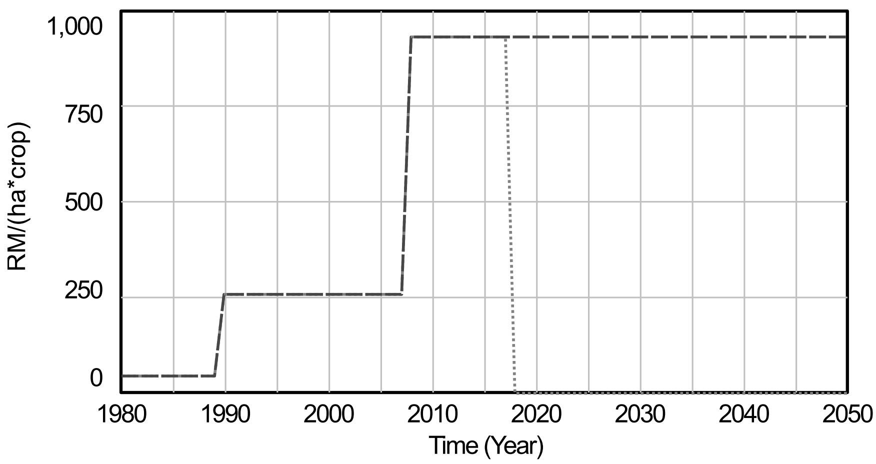
"Expected profitability per ha per year (EP)" : BAU
"Expected profitability per ha per year (EP)" : S2

(c) Expected variable cost per ha per year



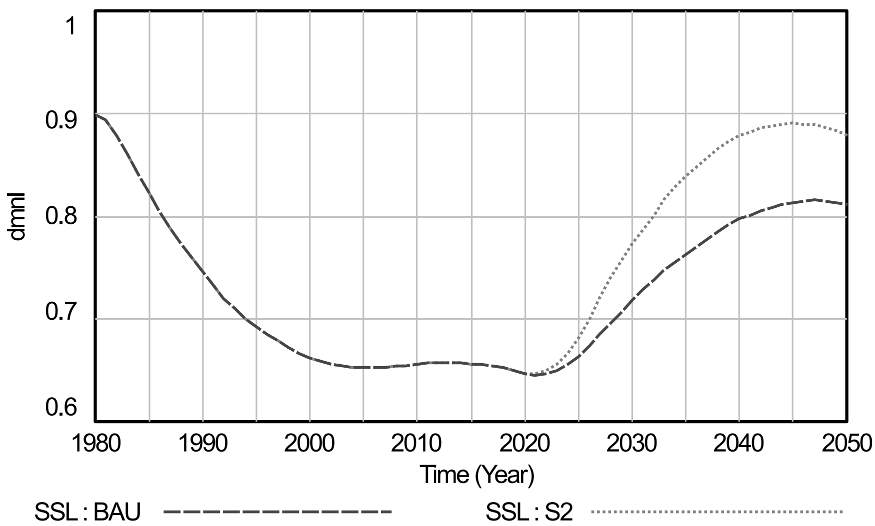
Expected variable cost per ha per year : BAU
Expected variable cost per ha per year : S2

(d) Subsidy on NL input

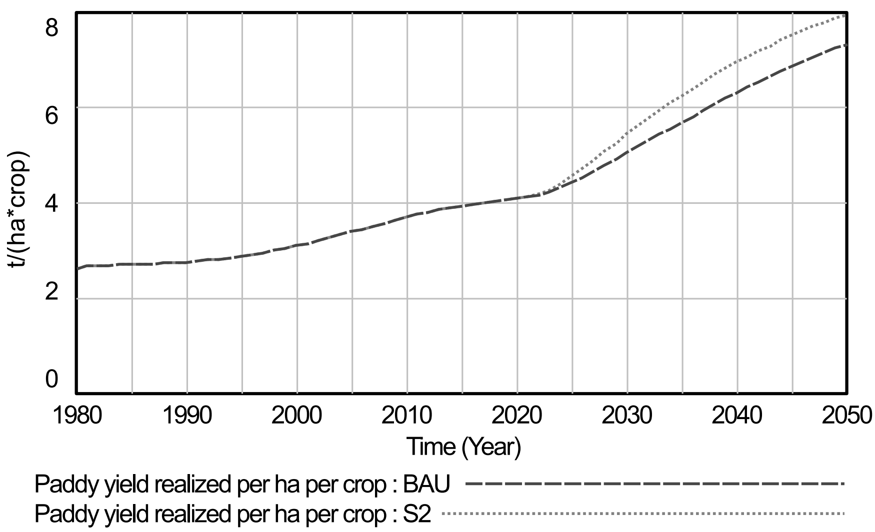


Subsidy on NL input : BAU
Subsidy on NL input : S2

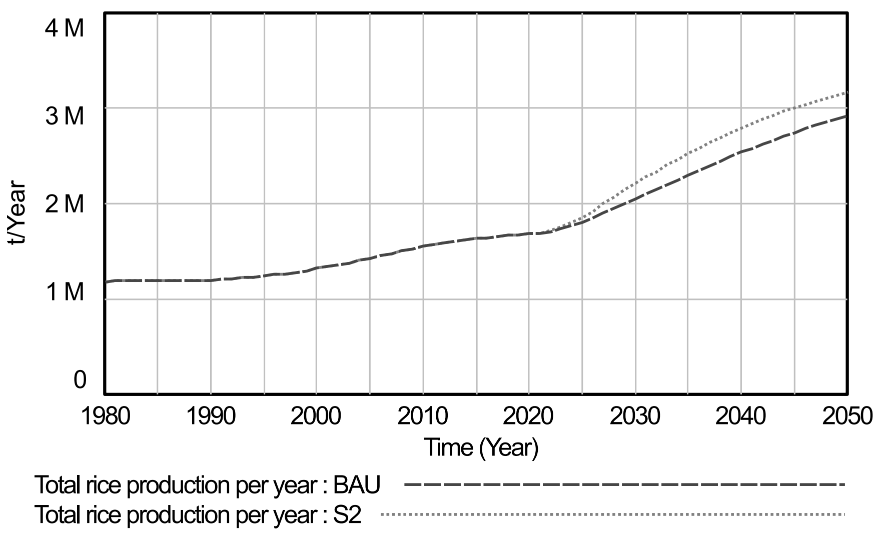
(e) SSL



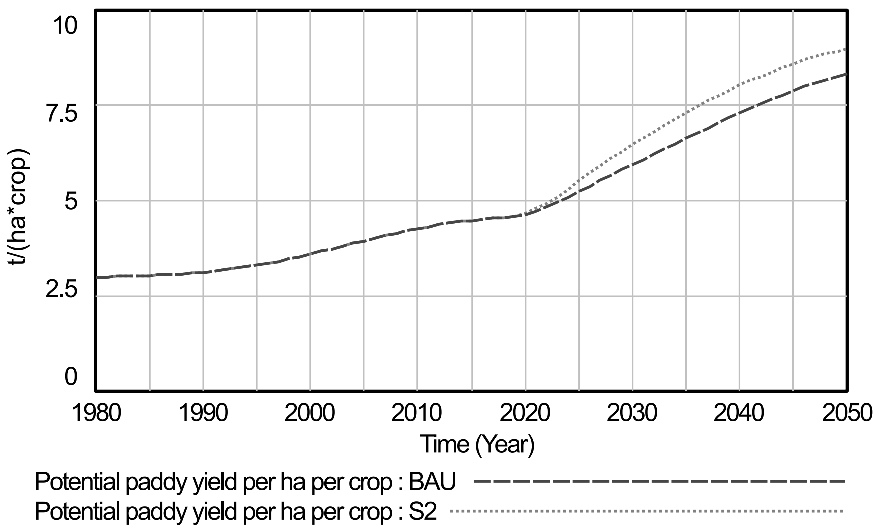
(f) Paddy realized per ha per crop



(g) Total rice production per year



(h) Potential paddy yield per ha per crop



Source: Authors, from model

Table 3.4 S2: Combination of Immediate Withdrawal of Input Subsidy and Strategy to Improve Yield

Variable	Base run	S2
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	29,965
POBR		1.06
COBR%		6.5
2018-2050 Absolute change	21,768	23,592
PCOB	341.5	370.2
b) Expected Profitability per ha per year (EP) (Ratio)		
1980 (Initial year)	4.1	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.6	1.6
POBR		0.95
COBR%		-4.8
2018-2050 Absolute change	-2.0	-2.0
PCOB	-54.7	-56.9
c) Expected variable cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-
2018 (Beginning of change)	1,770	1,770

COBR%		0
2050 (Simulation ends)	17,260	19,313
POBR		1.12
COBR%		11.9
2018-2050 Absolute change	15,490	17,543
PCOB	875.1	991.1
d) Subsidy on NL Input (RM/ha)		
1980 (Initial year)	45	-
2017 (Before change)	931	-
2018 (Beginning of change)	931	0
COBR%		-100.0
2050 (Simulation ends)	931	0
POBR		0
COBR%		-100.0
2018-2050 Absolute change	0	0
PCOB	0	0
e) SSL (%)		
1980 (Initial year)	0.90	-
2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.88
POBR		1.08
COBR%		8.4
2018-2050 Absolute change	0.2	0.2
PCOB	24.4	34.8
f) Paddy yield realized per ha per crop (t/ha)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	8.0
POBR		1.1
COBR%		8.4
2018-2050 Absolute change	3.3	3.9
PCOB	81.5	96.6
g) Total rice production per year (t/ha/year)		
1980 (Initial year)	1,172,929	-
2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0
2050 (Simulation ends)	2,918,697	3,162,479
POBR		1.08
COBR%		8.4

2018-2050 Absolute change	1,252,409	1,496,191
PCOB	75.2	89.8
h) Potential paddy yield per ha per crop (t/ha/crop)		
1980 (Initial year)	3.0	-
2017 (Before change)	4.5	-
2018 (Beginning of change)	4.6	4.6
COBR%		0
2050 (Simulation ends)	8.3	9.0
POBR		1.08
COBR%		8.0
2018-2050 Absolute change	3.8	4.4
PCOB	82.6	97.1

Notes: POBR is Policy over base run, COBR% is Percentage change over base run, and PCOB is Percentage change over base year
Source: Authors, from model

The key takeaways of this simulation (S2) are:

- This policy simulates the combination of immediate withdrawal of the input subsidy and RDE strategy to improve yield.
- It results in an increase of the *Expected variable cost per ha per year* by about one-tenth but compensated by an increase in *Paddy yield realized per ha* per crop by 8% compared to the BAU figure.
- Impacted variables experience reasonable improvement. For instance, *Net revenue per ha per year* improves by 7%, *Total rice production per year* and *SSL* increase each by 8%.
- The reasonable increase in yield, production and SSL indicates the dominance of the R&D for yield growth loop.

3.2.3 S3: Continuous Increase in Input Subsidy

S3 examines the consequences of a continuous increase of input subsidy to the producers while output subsidies remain unchanged. Table 3.2 and Figure 3.3(d) show an annual increase of about RM50 to the existing NL input subsidy. The immediate loops affected are NL input cost and NL input and profitability in the Farm: Input sub-system. As described in S1 and S2, these two loops influence paddy production, SSL and R&D in the RDE sub-system. *NL input cost per ha per crop*, together with *labour cost per ha per crop* determine the *Expected variable cost per ha per year* and hence *Net revenue per ha per year* in the Farm: Revenue sub-system.

The continuous increase in subsidy reduces the cost burden to the producers. Under the base run, the *Expected variable cost per ha per year* increases eight times from RM1,770 (2018) to RM17,260. Under this policy, the increase in *Expected variable cost per ha per year* is a lot lesser, i.e., it only reaches RM14,531 or a seven-folds increase. The POBR ratio is 0.84 indicating that the simulated value of variable cost is about 15.8% lower than the base run in 2050 which indicates an improvement.

The reduction in the *Expected variable cost per ha per year* improves the *Expected profitability per ha per year (EP)* or mark-up which determines the input use in the Farm: Input sub-system. The *Expected profitability per ha per year (EP)* begins to decline slowly after an increasingly upward trend since 2018 until 2050. Unlike S1 and S2, the EP remains above the base value (Figure 3.3(b)). The *EP* decreases by 41% from 3.6 to 2.1 under simulation run while under BAU it reduces by half.

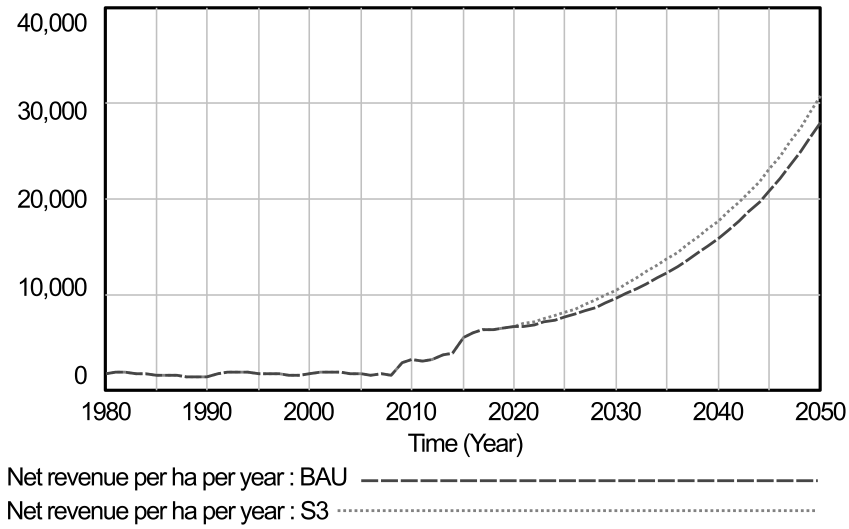
The reduction in the *EP* demotivates the producers from increasing input use (NL input and labour) due to low yield profile. This results in unchanged paddy yield level under the new policy run. As shown in Table 3.5 and Figure 3.3, *Paddy yield realised per ha per crop*, *SSL* and *Total rice production per year* remain at the BAU levels in 2050.

However, the producers gain the benefit of higher revenue due to the reduction in cost. As shown in Figure 3.3a and Table 3.5, the *Net revenue per ha per year* increases from RM6,374 in the base year to RM30,871, an increase of 3.8 times. Under the base run the increase is 3.4 times to RM28,141. The POBR ratio is 1.10 indicating that the simulation value is one-tenth higher than the base run value in 2050.

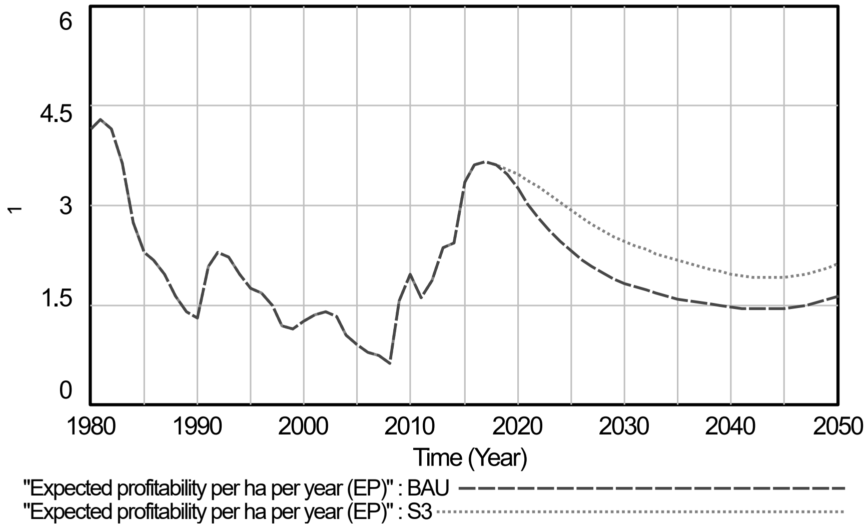
In conclusion, the continuous input subsidy allocation reduces the cost burden to the producers and hence improves revenue. However, the increase in the revenue is not adequate to incentivise the producer to increase input use due to low yield profile of paddy, in that additional input may not lead to an increase in yield. This indicates the dominance of R&D in yield growth loop in affecting yield performance.

Figure 3.3 S3: Continuous Increase in Input Subsidy, 1980 – 2050

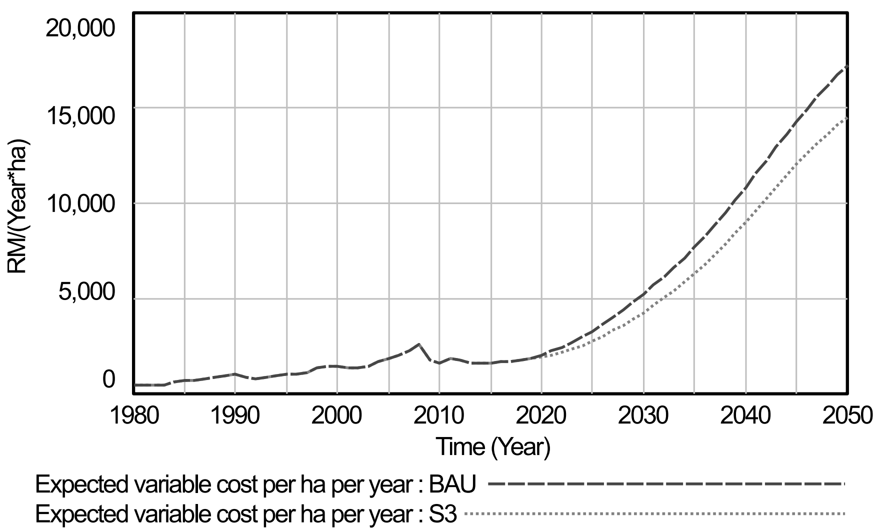
(a) Net revenue per ha per year



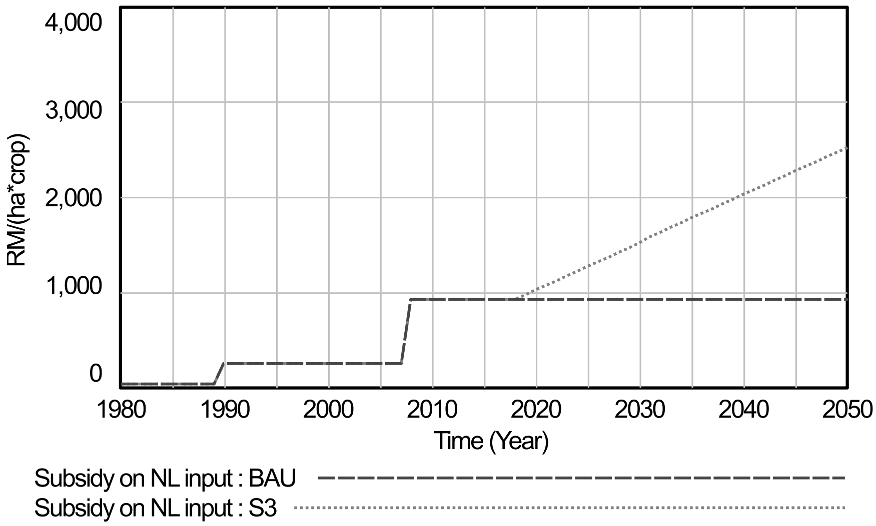
(b) Expected profitability per ha per year (EP)



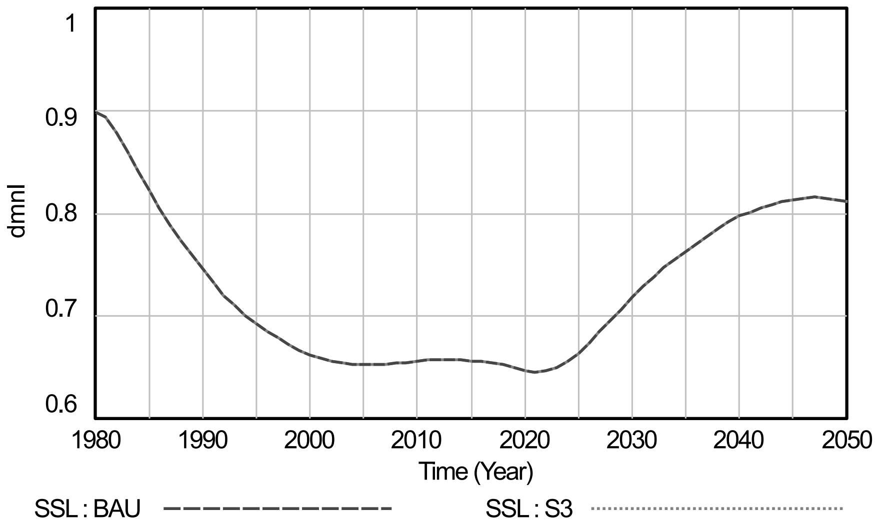
(c) Expected variable cost per ha per year



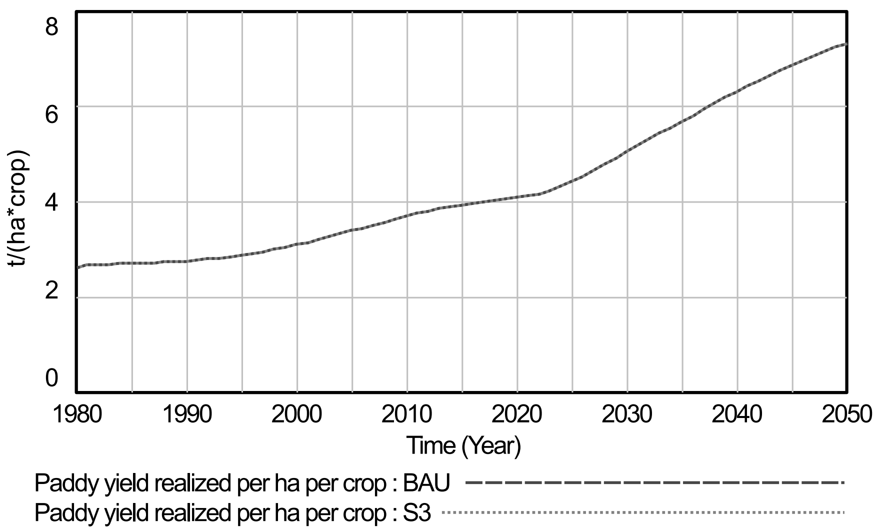
(d) Subsidy on NL input



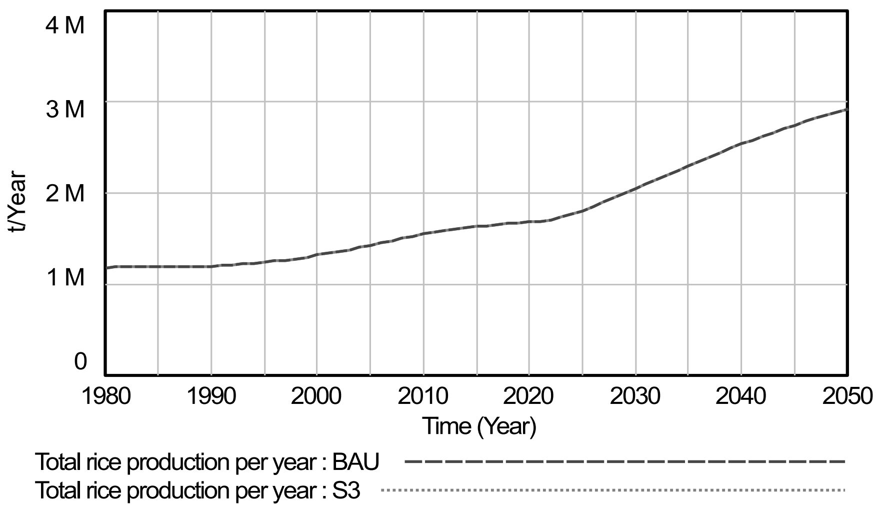
(e) SSL



(f) Paddy yield realized per ha per crop



(g) Total rice production per year



Source: Authors, from model

Table 3.5 S3: Continuous Increase in Input Subsidy

Variable	Base run	S3
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	30,871
POBR		1.10
COBR%		9.7
2018-2050 Absolute change	21,768	24,497
PCOB	341.5	384.4
b) Expected profitability per ha per year (EP) (Ratio)		
1980 (Initial year)	4.1	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.6	2.1
POBR		1.30
COBR%		30.3
2018-2050 Absolute change	-2.0	-1.5
PCOB	-54.7	-41.0
c) Expected variable cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-
2018 (Beginning of change)	1,770	1,770

COBR%		0
2050 (Simulation ends)	17,260	14,531
POBR		0.84
COBR%		-15.8
2018-2050 Absolute change	15,490	12,761
PCOB	875.1	720.9
d) Subsidy on NL input (RM/ha)		
1980 (Initial year)	45	-
2017 (Before change)	931	-
2018 (Beginning of change)	931	931
COBR%		0
2050 (Simulation ends)	931	2,531
POBR		2.72
COBR%		172.0
2018-2050 Absolute change	0	1,600
PCOB	0	172.0
e) SSL (%)		
1980 (Initial year)	0.90	-
2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.81
POBR		1.00
COBR%		0
2018-2050 Absolute change	0.2	0.2
PCOB	24.4	24.4
f) Paddy yield realized per ha per crop (t/ha)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	7.3
POBR		1.0
COBR%		0
2018-2050 Absolute change	3.3	3.3
PCOB	81.5	81.5
g) Total rice production per year (t/ha/year)		
1980 (Initial year)	1,172,929	-
2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0

2050 (Simulation ends)	2,918,697	2,918,697
POBR		1.00
COBR%		0
2018-2050 Absolute change	1,252,409	1,252,409
PCOB	75.2	75.2

Notes: POBR is Policy over base run, COBR% is Percentage change over base run and PCOB is Percentage change over base year
Source: Authors, from model

The key takeaways of this simulation (S3) are:

- This policy simulates the continuous increase in input subsidy.
- It results in the reduction in the *Expected variable cost per ha per year* by 16% compared to the BAU figure.
- The *Net revenue per ha per year* increases by one-tenth but the policy fails to increase, rice production and SSL. The poor performance of these variables is attributed to the dominance of the R&D for yield growth and R&D for crop intensity loops.

3.2.4 S4: RDE Strategies to Improve Extension, Yield and Cropping Intensity

R&D has been proven as the effective driver of innovation and productivity improvement[80]. This simulation explores the impact of enhancing R&D capacity and related infrastructure to: (i) enhance paddy extension services, (ii) increase potential yield and (iii) increase cropping intensity. The changes made are shown in Table 3.2. The effects of this simulation are presented in Figure 3.6 and Table 3.4.

To increase the effect of R&D on yield is carried out by enhancing the *Effect of R&D on yield improvement* as in the case of S2. This leads to an increase in *Indicated potential yield per ha per crop* and later the *Potential paddy yield per ha per crop* stock (Figure 3.4g). Depending on the *Yield delay time* of extension function, the *Paddy yield realised per ha per crop* at the farm would increase accordingly.

To improve extension service is to reduce the *Yield delay time* from two to one year. Similarly, the *Paddy yield realised per ha per crop* and *Cropping intensity* are intensified by expediting the growth rate of progress in the R&D efforts and infrastructural development towards that end. As shown in Table 3.6, under BAU, the *Cropping intensity* is increased from 1.7 in 2018 to 1.8 in 2050, an increase of 3.4%. Under this policy, it increases to 2 in 2050, an increase of 14.8%. The increase in *Cropping intensity* expands the *Paddy planted area* by 7.2% from 660,855 ha to 708,106 ha. Under BAU the area reduces by 3.5% to 637,853 ha in 2050 (Fig. 3.6i).

By 2050, the simulated *Paddy realised yield per ha per crop* increases to 8 t/ha/crop

80 Fan S. (2000) and FAO (2009).

compared to 7.3 t/ha/crop under BAU indicating a 9.4% improvement (with a POBR ratio of 1.09). Over time, the *Paddy realised yield per ha per crop* improves by 81.5% between 2018 and 2050 compared to 98.5% under the simulation.

An improvement in *Paddy realised yield per ha per crop* increases the *Paddy sold per ha per crop* and hence the *Farmer revenue per ha per year*. Due to increase in *Paddy planted area* the *Expected variable cost per ha per year* increases by ten times under this run compared to eight times under the BAU. The cost increases from RM1,770/ha/year in 2018 to RM19,621/ha/year in 2050 under this run while it increases to RM17,260/ha/year under BAU. The *Net revenue per ha per year* improves 3.4 times under BAU, compared to the 4.5 times under this policy.

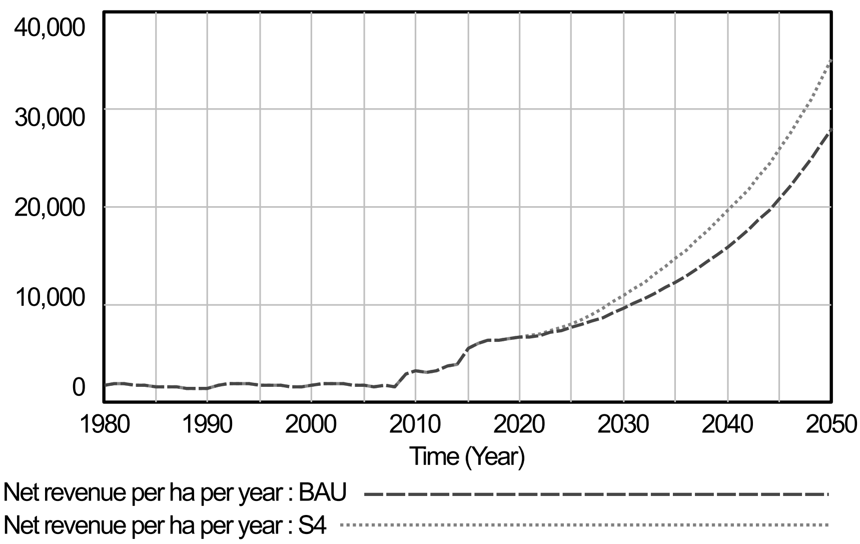
Under this simulation the *Total rice production per year* increases from 1.7m t/year in the base year to 3.5m t/year in 2050 compared to 2.9m t/year under BAU. This means production increases by 112.7% under simulation and 75.2% under BAU. The POBR ratio is 1.21 indicating that the simulated value is one-fifth higher than BAU in 2050.

With the increase in the *Total rice production per year*, *SSL* improves by one-fifth under this run that is from 81% under BAU compared to 98% in 2050 with a POBR ratio of 1.21. Overtime, *SSL* manages to improve by a 24.4% while it increases by 51% under this simulation.

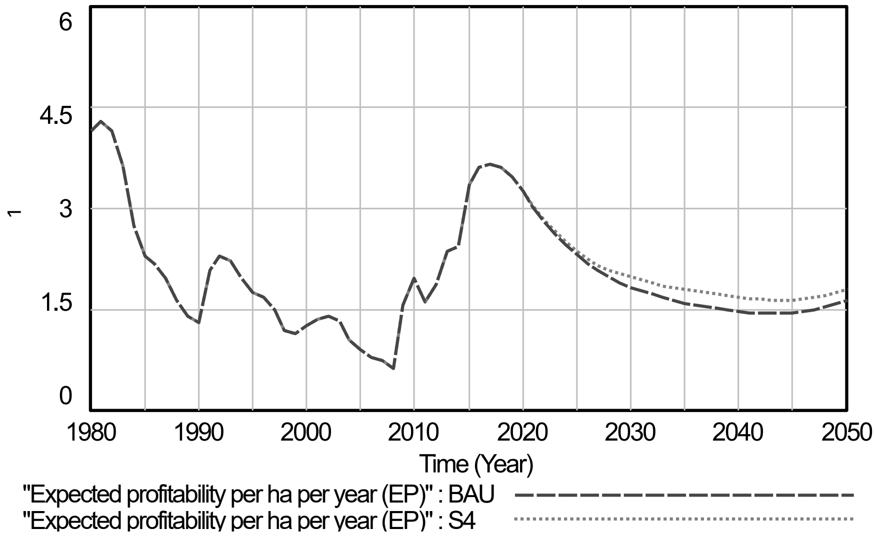
In conclusion, this simulation shows that the loops in the RDE sub-system are dominant in improving extension time, *Paddy realised yield per ha per crop* and *Cropping intensity* which are translated into higher *SSL*, *Total rice production per year* and better *Net revenue per ha per year* to the farmers.

Figure 3.4 S4: Combination of RDE Strategies to Improve Extension, Yield and Cropping Intensity, 1980 – 2050

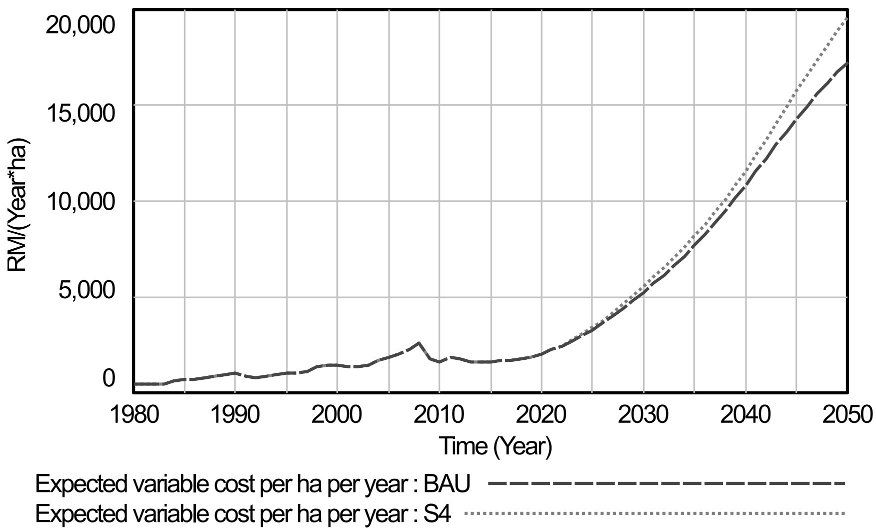
(a) Net revenue per ha per year



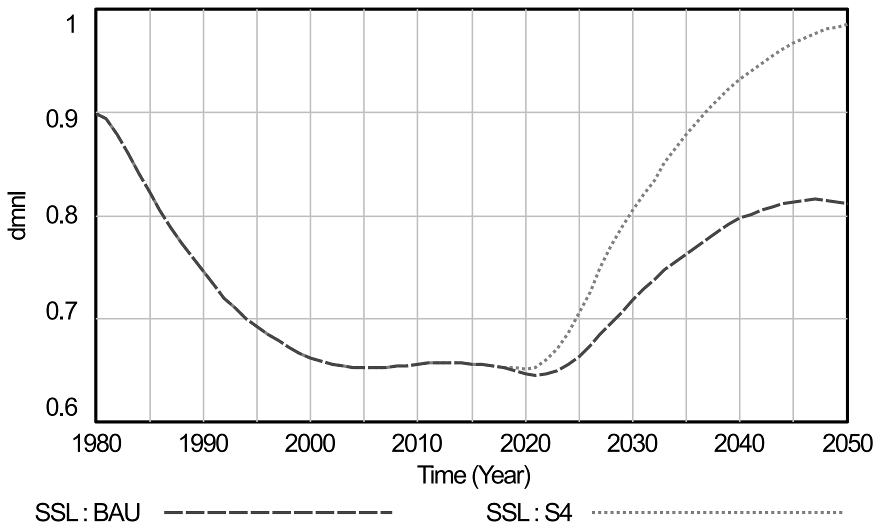
(b) Expected profitability per ha per year (EP)



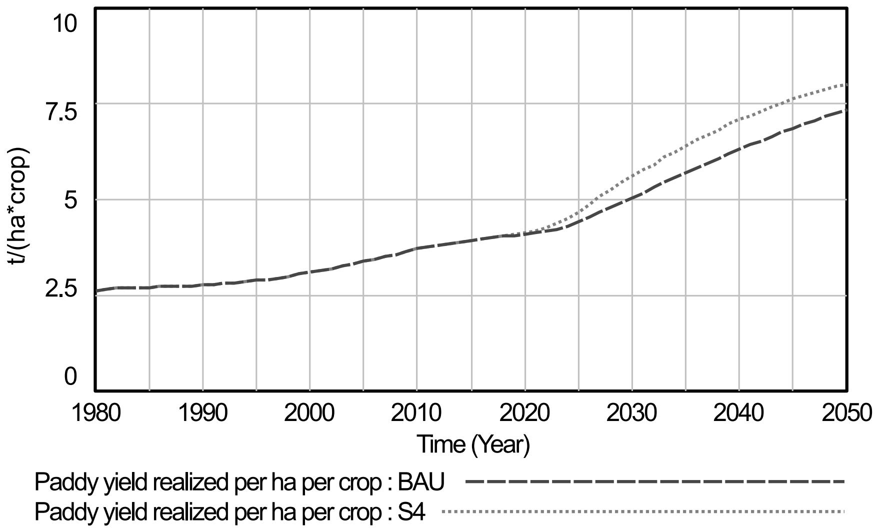
(c) Expected variable cost per ha per year



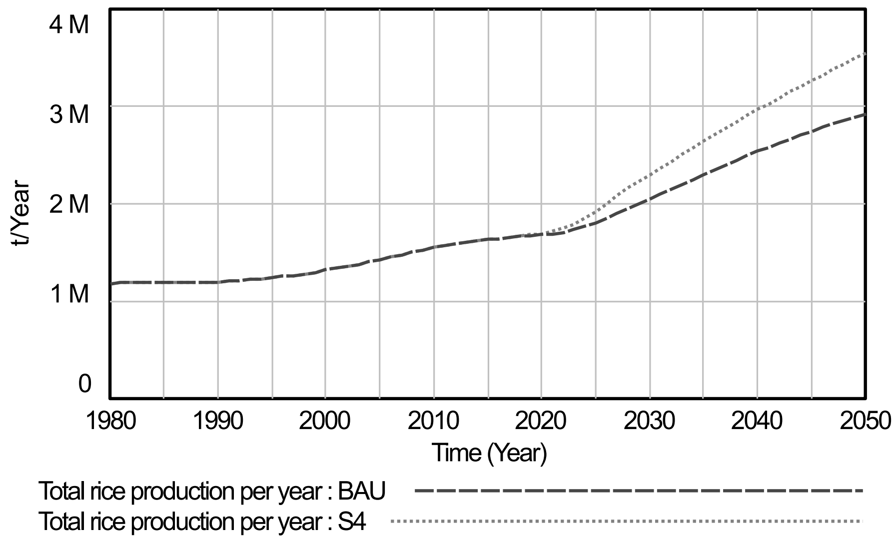
(d) SSL



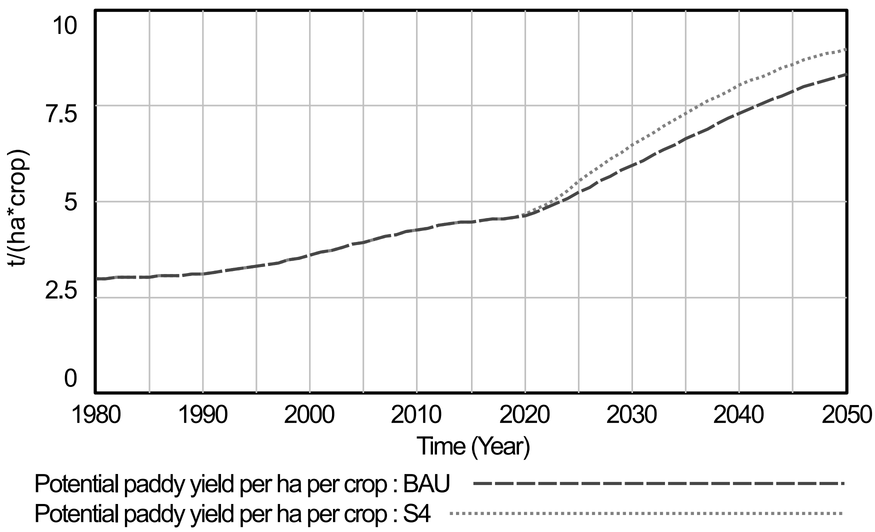
(e) Paddy yield realized per ha per crop



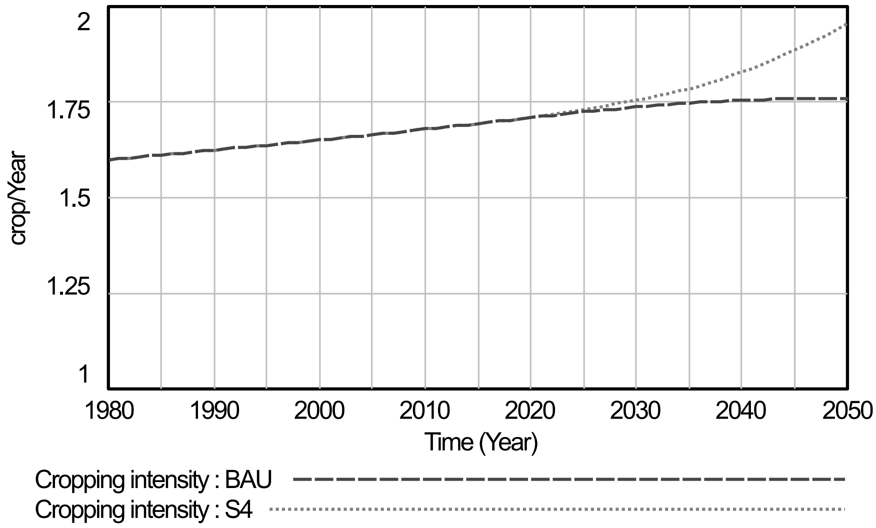
(f) Total rice production per year



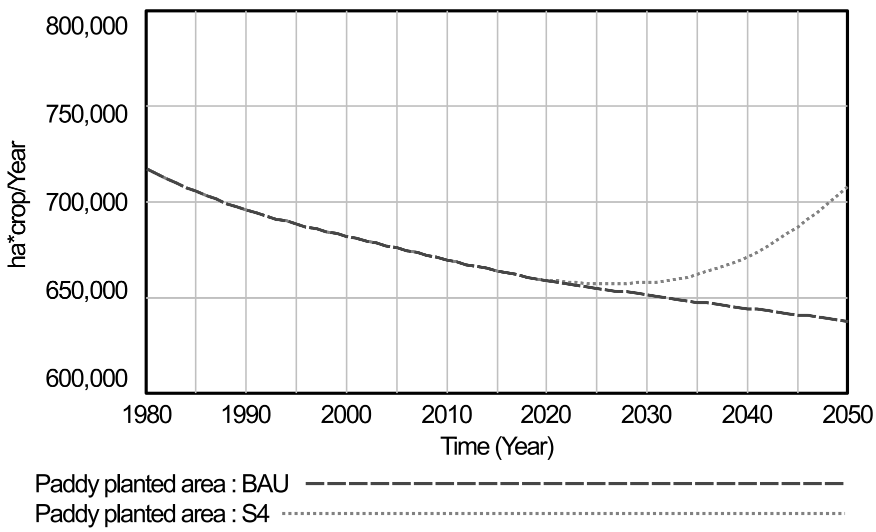
(g) Potential paddy yield per ha per crop



(h) Cropping intensity



(i) Paddy planted area



Source: Authors, from model

Table 3.6 S4: Combination of RDE Strategies to Improve Extension, Yield and Cropping Intensity

Variable	Base run	S4
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	35,242
POBR		1.25
COBR%		25.2

2018-2050 Absolute change	21,768	28,868
PCOB	341.5	452.9
b) Expected profitability per ha year (EP) (Ratio)		
1980 (Initial year)	4.1	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.6	1.8
POBR		1.10
COBR%		10.2
2018-2050 Absolute change	-2.0	-1.8
PCOB	-54.7	-50.1
c) Expected variable cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-
2018 (Beginning of change)	1,770	1,770
COBR%		0
2050 (Simulation ends)	17,260	19,621
POBR		1.14
COBR%		13.7
2018-2050 Absolute change	15,490	17,851
PCOB	875.1	1,008.5
d) SSL (%)		
1980 (Initial year)	0.90	-
2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.98
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	0.2	0.3
PCOB	24.4	51.0
e) Paddy yield realized per ha per crop (t/ha)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	8.0
POBR		1.09
COBR%		9.4
2018-2050 Absolute change	3.3	4.0
PCOB	81.5	98.5
f) Total rice production per year (t/ha/year)		
1980 (Initial year)	1,172,929	-

2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0
2050 (Simulation ends)	2,918,697	3,543,430
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	1,252,409	1,877,142
PCOB	75.2	112.7
g) Potential paddy yield per ha per crop (t/ha)		
1980 (Initial year)	3.0	-
2017 (Before change)	4.5	-
2018 (Beginning of change)	4.6	4.6
COBR%		0
2050 (Simulation ends)	8.3	9.0
POBR		1.08
COBR%		8.0
2018-2050 Absolute change	3.8	4.4
PCOB	82.6	97.1
h) Cropping Intensity (Ratio)		
1980 (Initial year)	1.6	-
2017 (Before change)	1.7	-
2018 (Beginning of change)	1.7	1.7
COBR%		0
2050 (Simulation ends)	1.7	2.0
POBR		1.11
COBR%		11.0
2018-2050 Absolute change	0.1	0.3
PCOB	3.4	14.8
i) Paddy Planted Area (ha)		
1980 (Initial year)	716,874	-
2017 (Before change)	661,845	-
2018 (Beginning of change)	660,855	660,855
COBR%		0
2050 (Simulation ends)	637,853	708,106
POBR		1.11
COBR%		11.0
2018-2050 Absolute change	-23,002	47,251
PCOB	-3.5	7.2

Notes: POBR is Policy over base run, COBR% is Percentage change over base run, and PCOB is Percentage change over base year
Source: Authors, from model

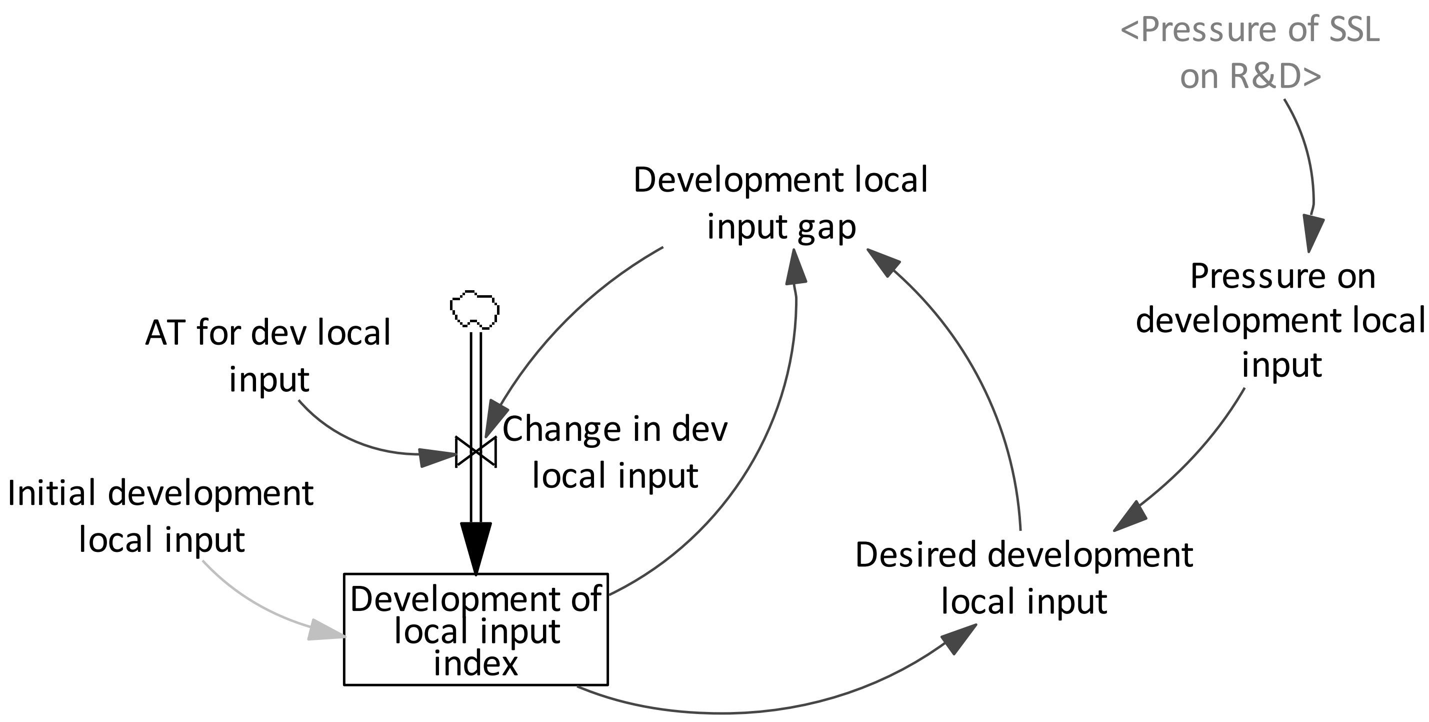
Key takeaways of this simulation (S4) are:

- This policy simulates the RDE strategies to improve extension, yield and cropping intensity
- Enhancing the three RDE functions is highly impactful.
- Delay time in extension is reduced, yield and cropping intensity (hence planted paddy area) are increased.
- *Paddy planted area* and *Paddy yield realised per ha per crop* increase by about one-tenth, *Net revenue per ha per year* improves by a quarter, *Total rice production per year* and *SSL* increase by one-fifth.
- These results point to the dominant roles of the R&D for yield growth, R&D and cropping intensity loops as well as improvement in the extension delay time affecting positively the impacted variables.

3.2.5 S5: Combination of S4 and Development of Local Input Sector

This simulation combines S4 and development of the local input sector to reduce the cost of production. The changes made on the model cover both those that are implemented under S4 and a new additional structure for the input sector development, as shown below.

Figure 3.5 Additional Structure on the Development of Local Input Sector



The development of local input sector starts with the *Pressure of SSL on R&D* which creates the *Desired development of local input.* The latter is calculated as follow;

> Desired development local input = Development of local input index*Pressure on development local input [3.1]
> Units: index

The difference between *Development of local input index* and *Desired development local input* is called *Development local input gap* which determines the rate that goes into the *Development local input index* stock. The rate is also influenced by time factor as well as the initial value. The *Development of local input index* is then inserted in the main model through the *Unit NL cost after 2018* stock in the Farm: Input sub-system.

This run combines the impact of S4 and development of local input sector which is expected to reduce the variable cost to the farmers. The combined impacts of this run are summarised in Figure 3.6 and Table 3.7.

The impact of the local input development can be seen on the *Unit NL cost after 2018*. Under the BAU run, the unit *NL cost after 2018* increases to 43.9 in 2050 from the base year value of 10.3 indicating an increase of three-fold (Figure 3.6c). However, under this policy, the increase is much lower that is about 1.2 times of its base value at 10.3. The POBR ratio is 0.53 indicating that the simulation value is lower by half of that under BAU in 2050.

The reduction in the *unit NL cost after 2018* helps to reduce the *Expected variable cost per ha per year*. The variable cost *increases* by eight-folds under the base run between 2018 and 2050 compared to five-folds under this simulation. The simulated *Expected variable cost per ha per year* of RM11,337 in 2050 is about two-thirds of BAU figure of RM17,260.

Unlike in the S1 – S3 simulations, the *Expected profitability per ha per year (EP)* shows an upward trend (Figure 3.6b). Under BAU, it reduces by half but under this run it increases from 3.6 in the base year to 3.8 in 2050, an increase of 6.6%. The POBR ratio is 2.35 indicating the simulated *Expected profitability per ha per year (EP)* is 135.5% above BAU value in 2050. Better expected markup incentivises farmers to increase input use. This leads to an increase in the *NL input use index per ha per crop* and *Labour use per ha per crop* stocks. These in turn improves the *paddy yield realized per ha per crop*.

All the above developments cause *Net revenue per ha per year* to increase five-folds whereas it is only three-folds under the BAU run. The POBR ratio is 1.55 which means the simulated value is 54.7% more than the base run value in 2050. The *Net revenue per ha per year* reaches RM43,526 an increase of five-folds compared to RM28,141 an increase of three-folds between the base year and 2050.

As in S4, the *Paddy planted area* increases as *Cropping intensity* moves from 1.7 in 2018 to 2 with the new policy injection. Similarly the *Paddy planted area* increases in the same magnitude as in S4. On the other hand, the reduction in the *Yield delay time* increases the *Potential paddy yield per ha per crop* and eventually the *Paddy yield realised per ha per crop*. The *Potential paddy yield per ha per crop* increases from 4.6 to 9 t/ha/crop between base and simulation year, an increase of 97.1% compared to 82.6% under base run.

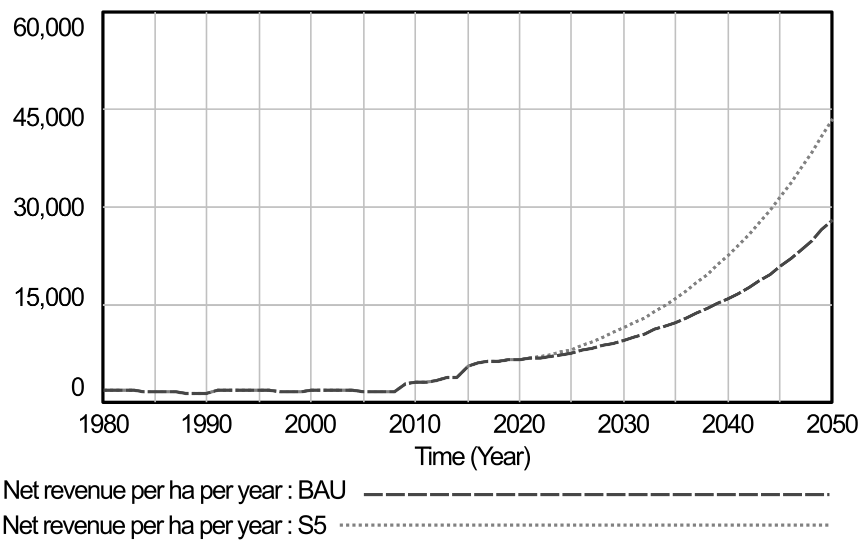
The *Paddy yield realised per ha per crop* increases from 7.3 to 8 t/ha/crop under this simulation an increase of 98.5% while under BAU it is 81.5%.

Similarly the *Total rice production per year* increases from 1.7m t/year in the base year to 2.9m t/year under BAU compared to 3.5m t/year in 2050 with the simulation. As for *SSL*, the simulation results in an *SSL* of 98% compared to 81% under BAU.

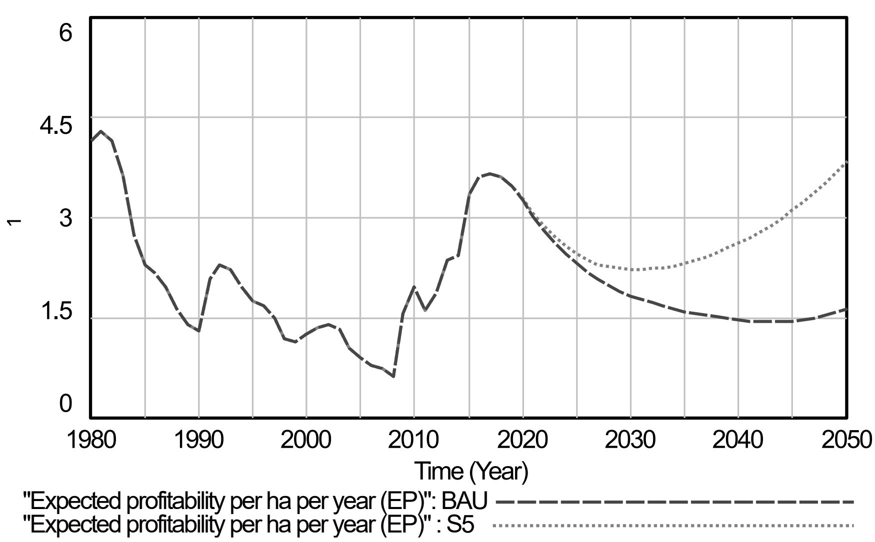
In a nutshell, this combination is highly effective as the RDE is intensified to improve extension, yield and cropping intensity and development of local input is activated. This policy package significantly improves *Paddy yield realised per ha per crop, Total rice production per year, SSL*, reduces *Expected variable cost per ha per year* and hence increases *Farmer revenue per ha per year*. These two strategies address the fundamental problems facing the industry i.e., low yield and high variable costs.

Figure 3.6 S5: Combination of S4 and Development of Local Input Sector, 1980 – 2050

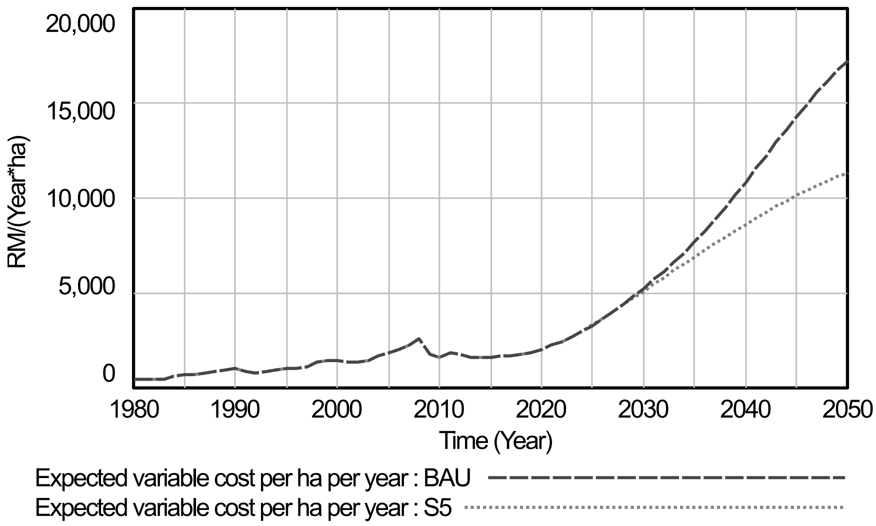
(a) Net revenue per ha per year



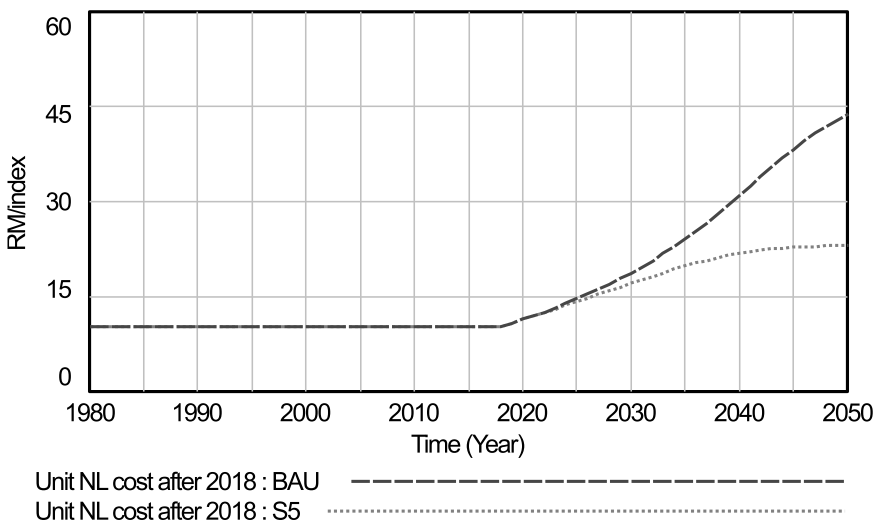
(b) Expected profitability per ha per year (EP)



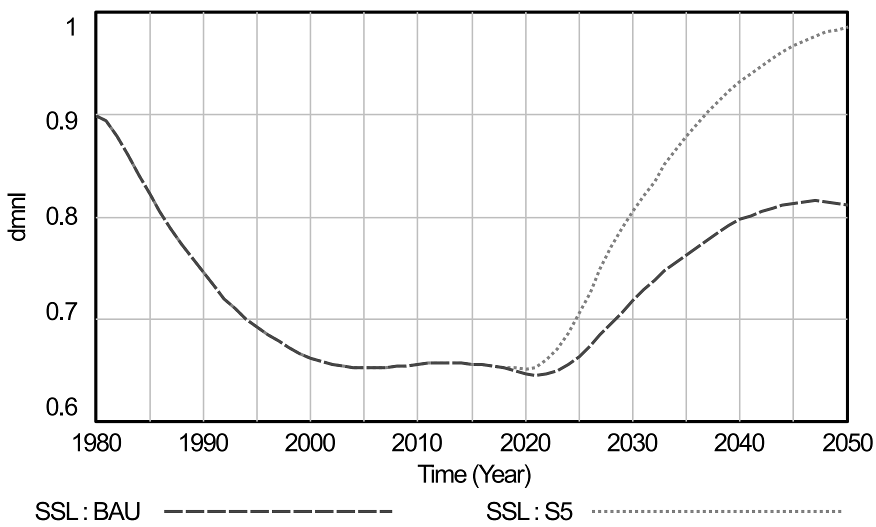
(c) Expected variable cost per ha per year



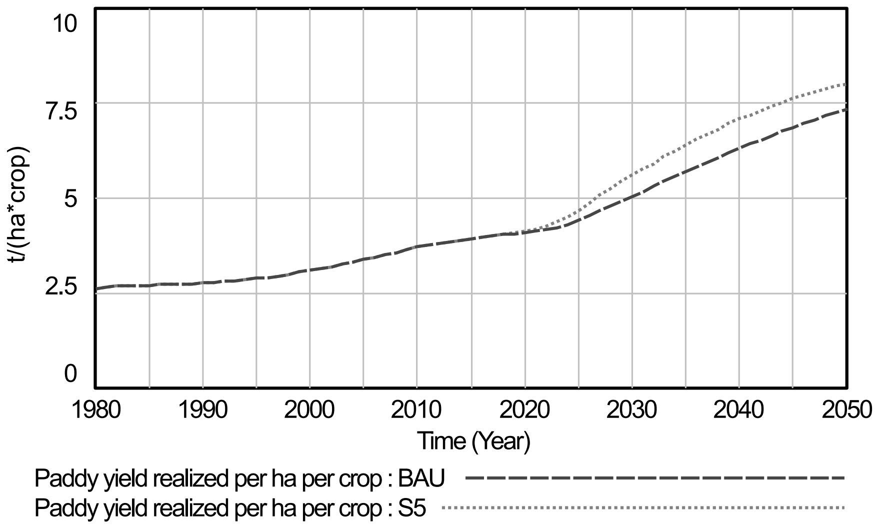
(d) Unit NL cost after 2018



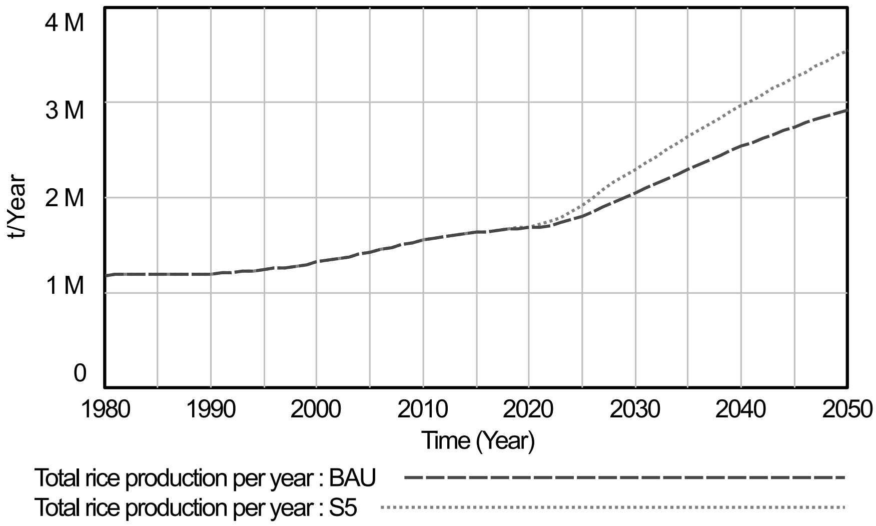
(e) SSL



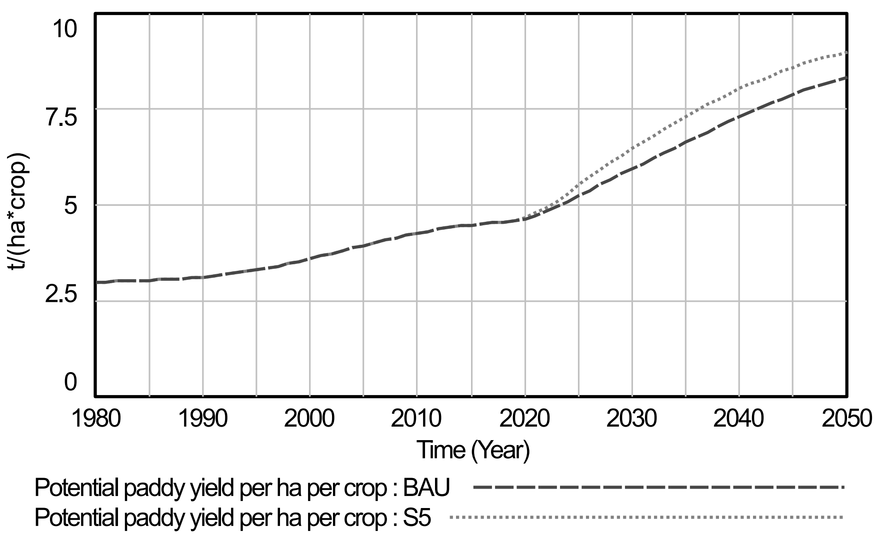
(f) Paddy yield realized per ha per crop



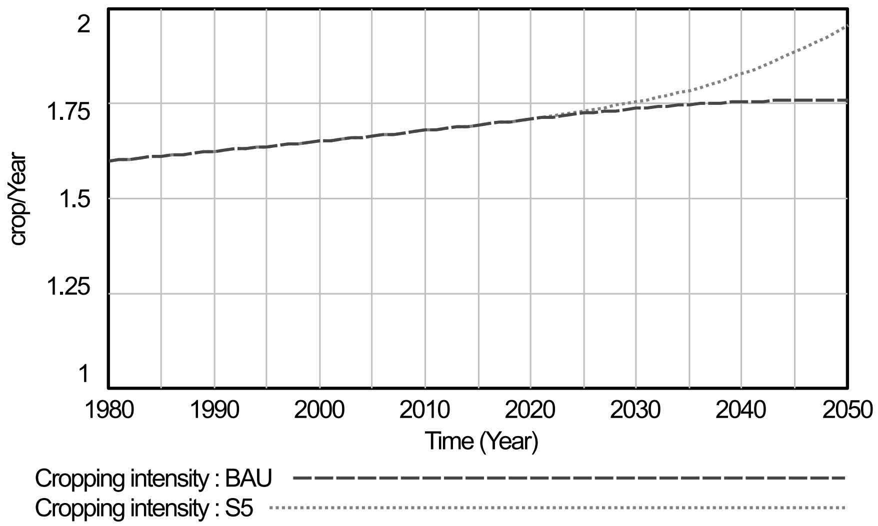
(g) Total rice production per year



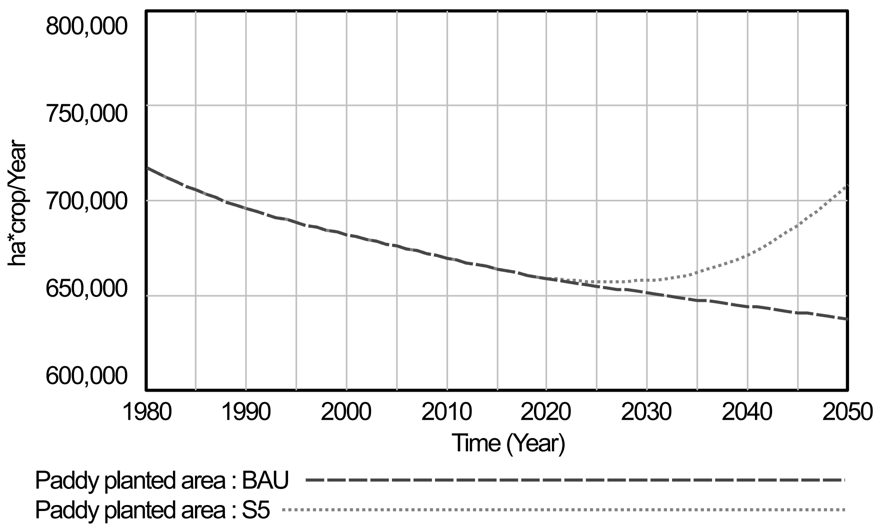
(h) Potential paddy yield per ha per crop



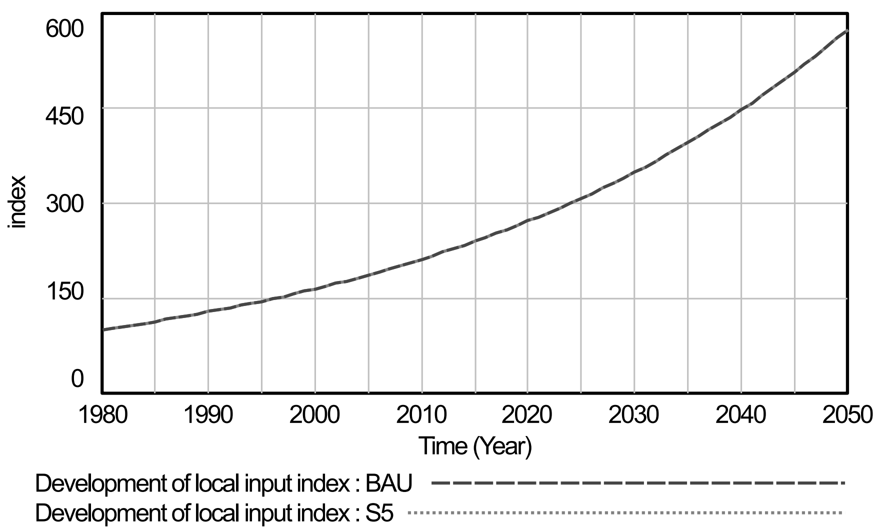
(i) Cropping intensity



(j) Paddy planted area



(k) Development of local input index



Source Authors, from model

Table 3.7 S5: Combination of S4 and Development of Local Input Sector

Variable	Base run	S5
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	43,526
POBR		1.55
COBR%		54.7
2018-2050 Absolute change	21,768	37,152
PCOB	341.5	582.9
b) Expected profitability per ha per year (EP) (Ratio)		
1980 (Initial year)	4.1	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.6	3.8
POBR		2.35
COBR%		135.5
2018-2050 Absolute change	-2.0	0.2
PCOB	-54.7	6.6
c) Expected variable cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-
2018 (Beginning of change)	1,770	1,770
COBR%		0
2050 (Simulation ends)	17,260	11,337
POBR		0.66
COBR%		-34.3
2018-2050 Absolute change	15,490	9,567
PCOB	875.1	540.5
d) Unit NL cost after 2018 (index)		
1980 (Initial year)	10.3	-
2017 (Before change)	10.3	-
2018 (Beginning of change)	10.3	10.3
COBR%		0
2050 (Simulation ends)	43.9	23.1
POBR		0.53
COBR%		-47.3
2018-2050 Absolute change	33.6	12.8
PCOB	325.8	124.3
d) SSL (%)		
1980 (Initial year)	0.90	-

2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.98
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	0	0
PCOB	24	51.0
e) Paddy yield realized per ha per year (t/ha/crop)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	8.0
POBR		1.09
COBR%		9.4
2018-2050 Absolute change	3.3	4.0
PCOB	81.5	98.5
f) Total rice production per year (t/ha/year)		
1980 (Initial year)	1,172,929	-
2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0
2050 (Simulation ends)	2,918,697	3,543,430
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	1,252,409	1,877,142
PCOB	75.2	112.7
g) Potential paddy yield per ha per crop (t/ha/year)		
1980 (Initial year)	3.0	-
2017 (Before change)	4.5	-
2018 (Beginning of change)	4.6	4.6
COBR%		0
2050 (Simulation ends)	8.3	9.0
POBR		1.08
COBR%		8.0
2018-2050 Absolute change	3.8	4.4
PCOB	82.6	97.1
h) Effect of R&D on yield improvement policy (dmnl)		
1980 (Initial year)	1.0	-
2017 (Before change)	1.6	-
2018 (Beginning of change)	1.6	1.6
COBR%		0
2050 (Simulation ends)	3.2	3.2

POBR		1.00
COBR%		0
2018-2050 Absolute change	1.6	1.6
PCOB	100.0	100.0
i) Cropping intensity (Ratio)		
1980 (Initial year)	1.60	-
2017 (Before change)	1.70	-
2018 (Beginning of change)	1.70	1.70
COBR%		0
2050 (Simulation ends)	1.76	1.95
POBR		1.11
COBR%		11.0
2018-2050 Absolute change	0.1	0.3
PCOB	3.4	14.8
j) Paddy planted area (ha)		
1980 (Initial year)	716,874	-
2017 (Before change)	661,845	-
2018 (Beginning of change)	660,855	660,855
COBR%		0
2050 (Simulation ends)	637,853	708,106
POBR		1.11
COBR%		11.0
2018-2050 Absolute change	-23,002	47,251
PCOB	-3.5	7.2

Notes: POBR is Policy over base run, COBR% is Percentage change over base run and PCOB is Percentage change over base year
Source: Authors, from model

Key takeaways of this simulation (S5) are:

- This policy simulates the combination of RDE strategies and development of the local input sector
- It results in the highest increase in the *Net revenue per ha per year* by half over BAU figure and biggest reduction in the *Expected variable cost per ha per year* by one-third.
- *Paddy planted area* and *Paddy yield realised per ha per crop* increase by about one-tenth, *Net revenue per ha per year* improves by a quarter, *Total rice production per year* and *SSL* increase by one-fifth.
- These results point to the dominant roles of the R&D for yield growth, R&D and cropping intensity loops as well as improvement in the extension delay time in affecting positively the said variables.
- This policy mix effectively addresses the major issues of low yield and high variable cost.

3.2.6 S6: Combination of S4 and S1 (Total Transfer of Input Subsidy to Output Subsidy)

This simulation comprises the RDE strategies (expediting extension, intensifying cropping intensity and improving yield) and subsidy restructuring from input to output sector. The changes made on the model are similar as in S4 and S1 respectively (Table 3.2). The results are presented in Figure 3.7 and Table 3.8.

As shown in S4, the three RDE strategies have a strong influence on yield, production and SSL. Improvement in yield gives positive effects on farmers' revenue and input use.

Since input subsidy is transferred to output, the farmers have to incur a higher *Expected variable cost per ha per year*. As shown in Figure 3.8c, the *Expected variable cost per ha per year* increases for both BAU and simulation runs. The *Expected variable cost per ha per year* under BAU increases by eight-folds between 2018 and 2050 while it increases eleven-folds under this policy. The POBR ratio is 1.24 indicating that the simulated *Expected variable cost per ha per year* (RM21,440) is 24% higher than the base value under BAU (RM17,260).

The *Expected profitability per ha per year (EP)* exhibits a more or less similar behaviour under S2. Due to the transfer of input subsidy to output subsidy, the *Expected profitability per ha per year (EP)* plunges steeply after 2018 below the BAU value. However, starting in 2033, the *Expected profitability per ha per year (EP)* begins to increase albeit very slowly by 2050 the POBR is 1.01, indicating no significant difference between the BAU and the simulation results. Incidentally, the 2050 values for both series are only 50% of the values in the base year.

The effect of the above developments on the net revenue is significant. The *Net revenue per ha per year* increases four-folds while under BAU it is three-folds. The POBR ratio in 2050 is 1.25, indicating that the simulated value is higher than the BAU value by a quarter. The *Net revenue per ha per year* reaches RM35,228 compared to RM28,141 in 2050.

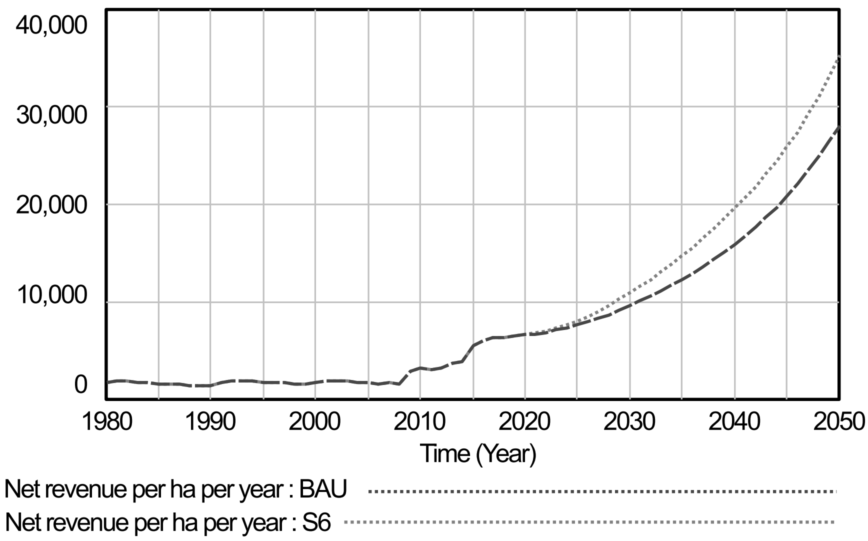
The new level of *Paddy yield realised per ha per crop* which is 8 t/ha is 9.4% higher than the *Paddy yield realised per ha per crop* under BAU run in 2050 with POBR ratio is 1.09. Similarly, the *Paddy yield realised per ha per crop* under BAU by 81.5% from the base year compared to 98.5% under this simulation.

The double impact of *Paddy yield realised per ha per crop* and *Cropping intensity* improvements are an increase of *Paddy planted area, Total rice production per year* and *SSL* which are similar as in under S5 and S6.

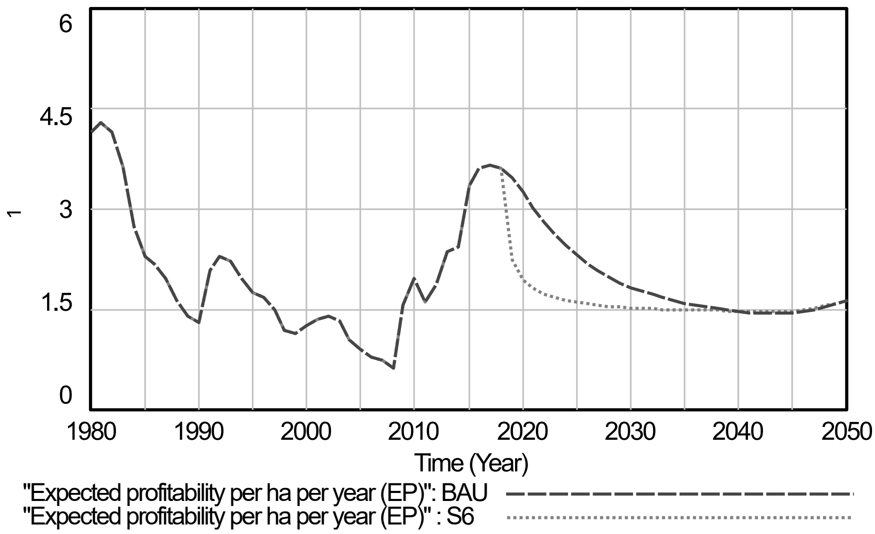
Like in the earlier simulations (S4 and S5), S6 is also effective in benefiting fully the potentials of the RDE sub-system and all the loops within it. The increase in *Paddy yield realised per ha per crop, Total rice production per year* and *SSL* under this run is in similar magnitude as in S5. Improvement in *Paddy yield realised per ha per crop* and *Total rice production per year* offsets the increase in *Expected variable cost per ha per year* due to the subsidy transfer resulting in a positive *Net revenue per ha per year* to the producers.

Figure 3.7 S6: Combination of S4 and S1 (Total Transfer of Input Subsidy to Output Subsidy), 1980 – 2050

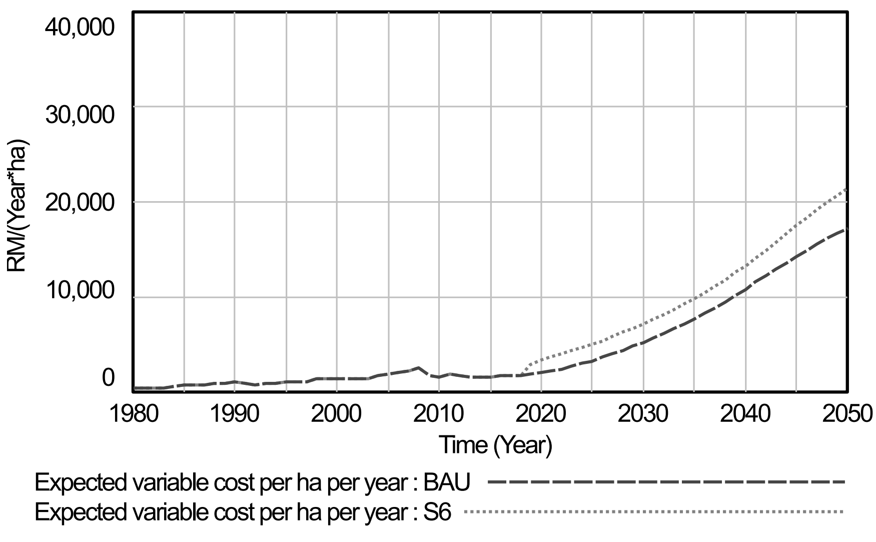
(a) Net revenue per ha per year



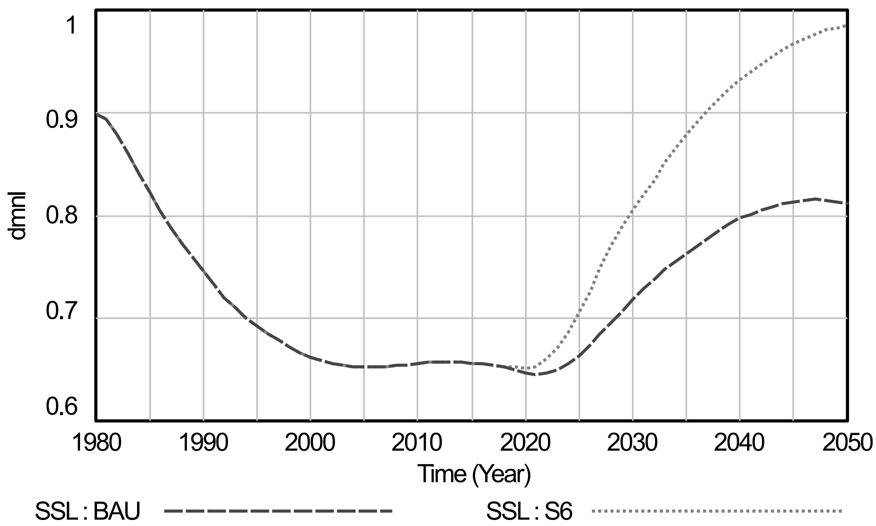
(b) Expected profitability per ha per year (EP)



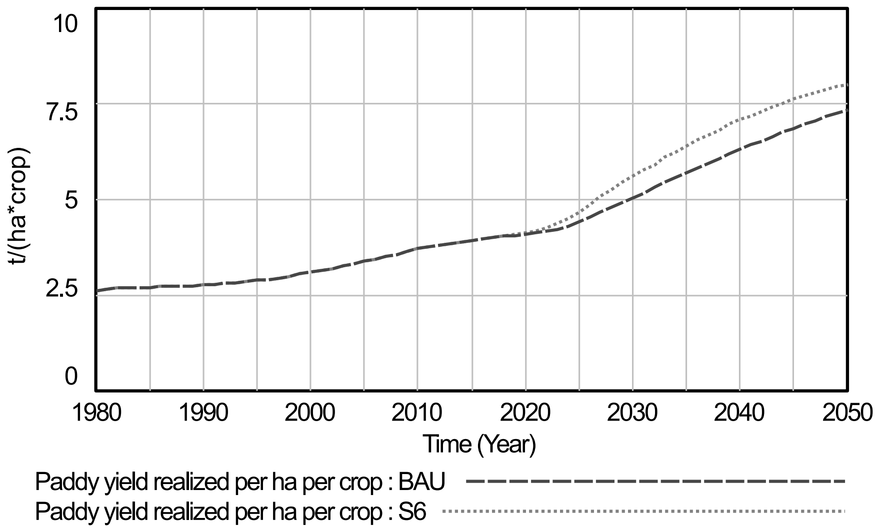
(c) Expected variable cost per ha per year



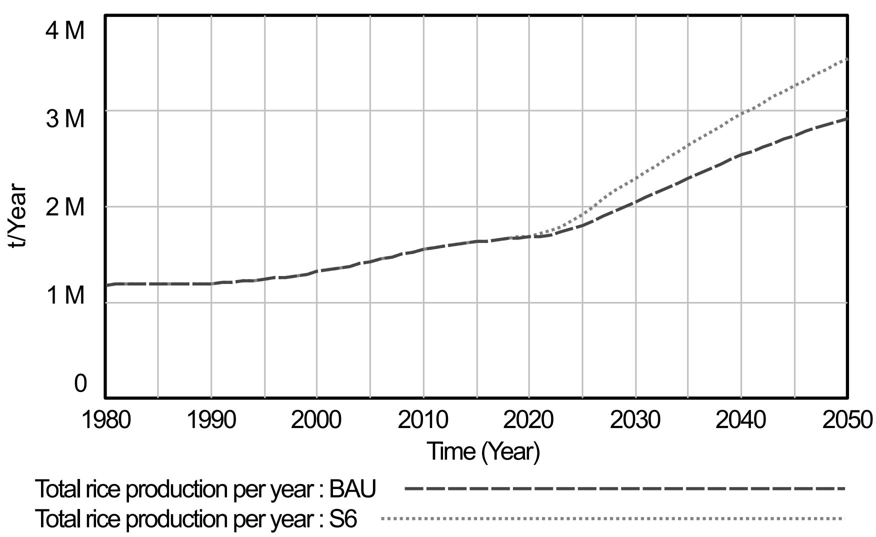
(d) SSL



(e) Paddy yield realized per ha per crop



(f) Total rice production per year



Source: Authors, from model

Table 3.8 S6: Combination of S4 and S1 (Total Transfer of Input Subsidy to Output Subsidy)

Variable	Base run	S6
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	35,228
POBR		1.25
COBR%		25.2
2018-2050 Absolute change	21,768	28,854
PCOB	341.5	452.7
b) Expected profitability per ha per year (EP) (Ratio)		
1980 (Initial year)	4.1	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.6	1.6
POBR		1.01
COBR%		0.8
2018-2050 Absolute change	-2.0	-2.0
PCOB	-54.7	-54.4
c) Expected variable cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-
2018 (Beginning of change)	1,770	1,770
COBR%		0
2050 (Simulation ends)	17,260	21,440
POBR		1.24
COBR%		24.2
2018-2050 Absolute change	15,490	19,670
PCOB	875.1	1,111.3
d) SSL (%)		
1980 (Initial year)	0.90	-
2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.98
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	0	0
PCOB	24	51.0

e) Paddy yield realized per ha per crop (t/ha)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	8.0
POBR		1.09
COBR%		9.4
2018-2050 Absolute change	3.3	4.0
PCOB	81.5	98.5
f) Total rice production per year (t/ha)		
1980 (Initial year)	1,172,929	-
2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0
2050 (Simulation ends)	2,918,697	3,543,430
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	1,252,409	1,877,142
PCOB	75.2	112.7

Notes: POBR is Policy over base run, COBR% is Percentage change over base run and PCOB is Percentage change over base year
Source: Authors, from model

Key takeaways of this simulation (S6) are:

- This policy simulates the combination of RDE strategies and total transfer of input subsidy to output subsidy.
- The transfer increases the *Expected variable cost per ha per year* by a quarter over the BAU figure.
- *Net revenue per ha per year* increases by a quarter.
- *Paddy yield realised per ha per crop* increase by about one-tenth, *Total rice production per year* and *SSL* increase by one-fifth.
- These results point to the dominant roles of the R&D for yield growth, R&D and cropping intensity loops as well as improvement in the extension delay time affecting positively the said variables.

3.2.7 S7: Combination of S4 and S2 (Immediate Withdrawal of the Input Subsidy)

This simulation examines the contributions of RDE in yield, extension and cropping intensity improvement and immediate withdrawal of input subsidy. The summary of impact is presented in Figure 3.8 and Table 3.9.

Like the earlier simulations (S4 – S6), the impact of the three strategies on *Paddy yield realized per ha per crop*, *SSL* and *Total rice production per year* are similar in behaviour and magnitude due to the similar path of causality and effect. Additional impacts are produced by the immediate withdrawal of input subsidy as shown in Table 3.2 and illustrated in Figure 3.8d.

Despite the input subsidy withdrawal (Figure 3.8d), the farmers bear the cost of NL input themselves to preserve their livelihood. The impact of the immediate withdrawal is a sudden increase in the variable cost between 2018 and 2019 and later moves to an upward trend. The *Expected variable cost per ha per year* increases by eight-folds between the base year and 2050 under BAU while it is about eleven-folds under this policy package. The POBR ratio is 1.24 indicating the simulated cost is about one-fifth higher than the BAU figure. The behaviour of the cost is similar to S6 (Figure 3.9c).

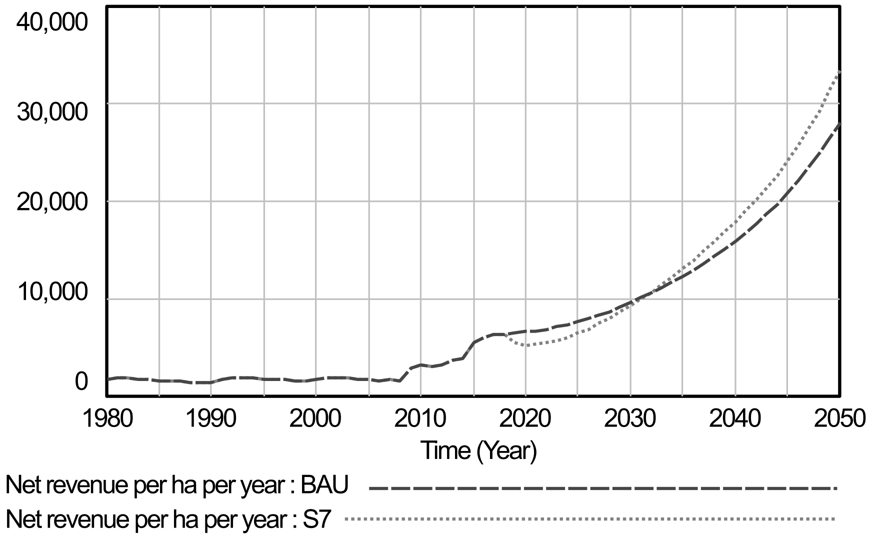
The *Expected profitability per ha per year (EP)* reduces by half from 3.6 in the base year to 1.6 in 2050 under BAU. Under this simulation, its value reduces by 56.7%. As shown in Fig 3.9b, after the sharp decline in *Expected profitability per ha per year (EP)* in 2018 it begins to plateau. By 2050 its value reaches 1.63 compared to 1.56 under BAU with the POBR ratio of 0.96 indicating a minimal change in the variable.

The withdrawal of input subsidy causes the *Net revenue per ha per year* under this policy to be below the BAU value but around 2026 it begins to catch up. By 2050 the simulated value is above the BAU value. The *Net revenue per ha per year* under this simulation increases by four-folds, that is from RM6,374 to RM33,423 while under BAU it manages to increase three-folds to RM28.141. The POBR ratio is 1.19 that is the simulated value is higher than the BAU value by about one-fifth.

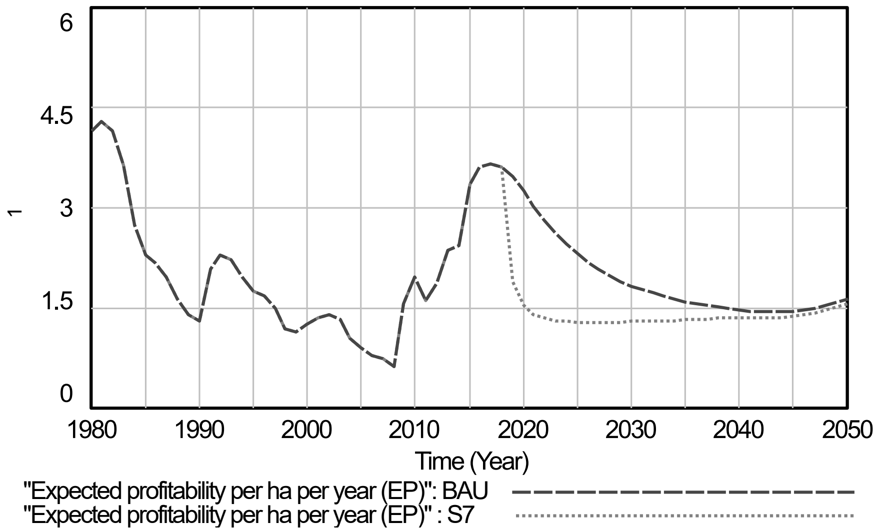
In conclusion, the immediate withdrawal reduces the revenue in the short term but in the long term it improves beyond the BAU value. It goes to show that the withdrawal does not reduce producers' *Net revenue per ha per year* if the RDE roles (extension, yield and cropping intensity improvement) are at work. It also emphasises the dominant role of the RDE sub-system in inducing production growth and income improvement of the farmers.

Figure 3.8 S7: Combination of S4 and S2 (Immediate withdrawal of the Input Subsidy), 1980 – 2050

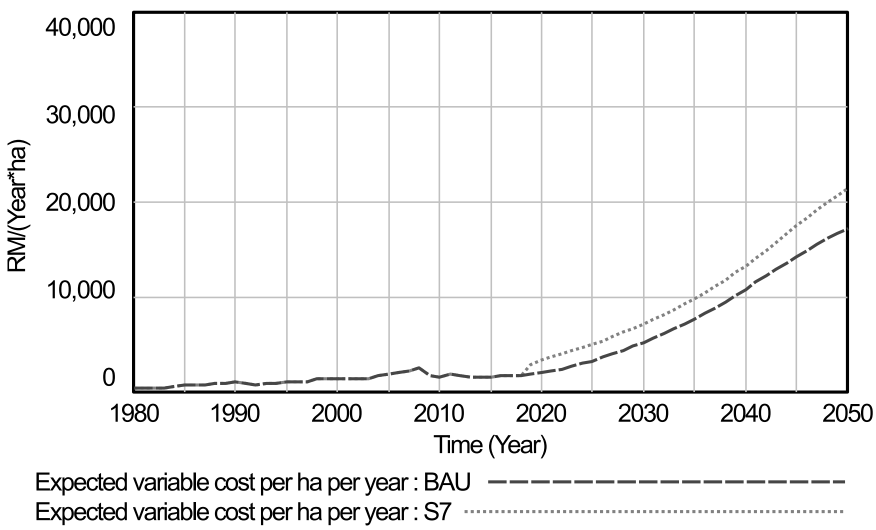
(a) Net revenue per ha per year



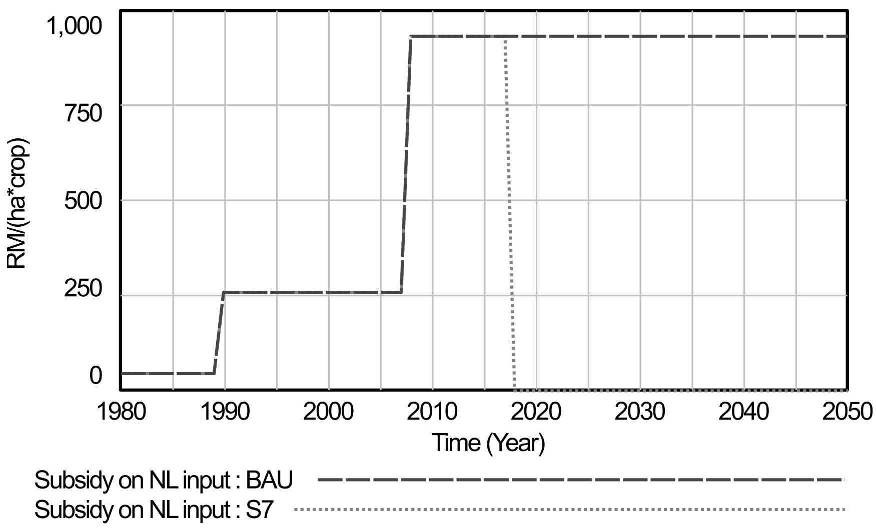
(b) Expected profitability per ha per year (EP)



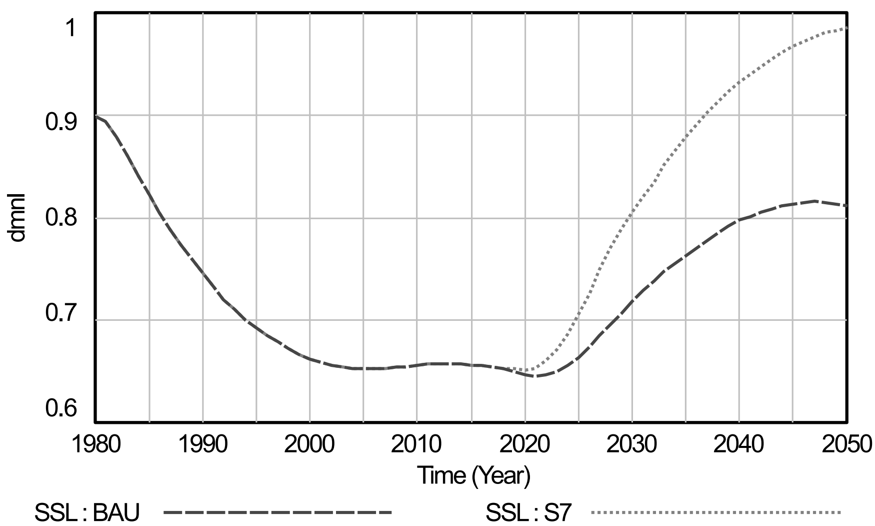
(c) Expected variable cost per ha per year



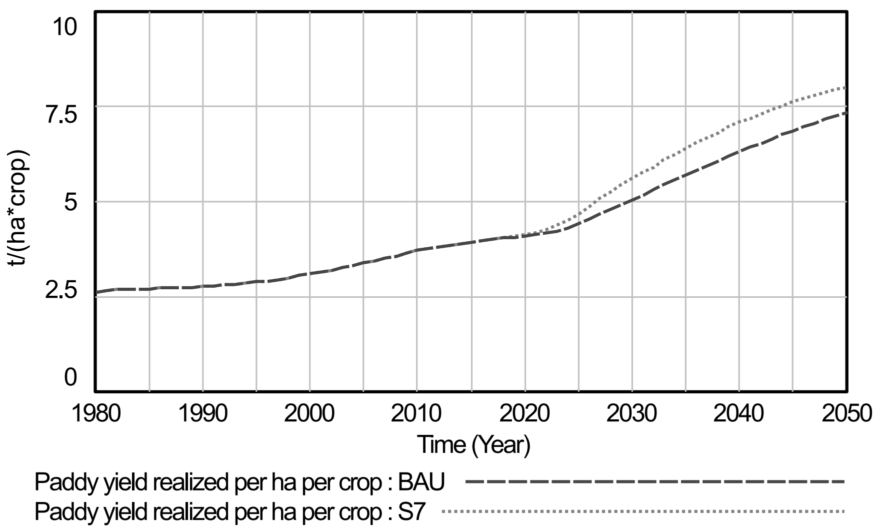
(d) Subsidy on NL input



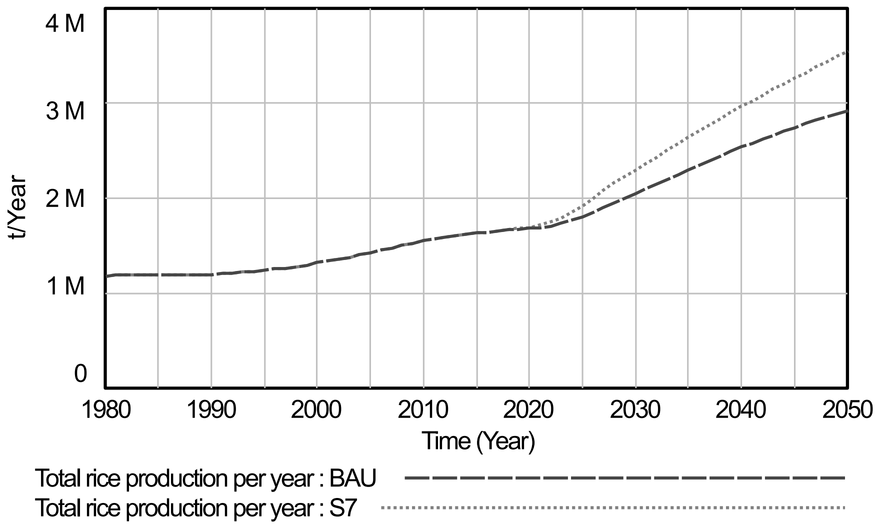
(e) SSL



(f) Paddy yield realized per ha per crop



(g) Total rice production per year



Source: Authors, from model

Table 3.9 S7: Combination of S4 and S2 (Immediate withdrawal of the Input Subsidy)

Variable	Base run	S7
a) Net revenue per ha per year (RM/ha/year)		
1980 (Initial year)	1,788	-
2017 (Before change)	6,275	-
2018 (Beginning of change)	6,374	6,374
COBR%		0
2050 (Simulation ends)	28,141	33,423
POBR		1.19
COBR%		18.8
2018-2050 Absolute change	21,768	27,049
PCOB	341.5	424.4
b) Expected profitability per ha per year (EP) (Ratio)		
1980 (Initial year)	4.2	-
2017 (Before change)	3.7	-
2018 (Beginning of change)	3.6	3.6
COBR%		0
2050 (Simulation ends)	1.63	1.56
POBR		0.96
COBR%		-4.4
2018-2050 Absolute change	-2.0	-2.0
PCOB	-54.7	-56.7
c) Expected variable cost per ha per year (RM/ha/year)		
1980 (Initial year)	431	-
2017 (Before change)	1,719	-

2018 (Beginning of change)	1,770	1,770
COBR%		0
2050 (Simulation ends)	17,260	21,440
POBR		1.24
COBR%		24.2
2018-2050 Absolute change	15,490	19,670
PCOB	875.1	1,111.3
d) Subsidy on NL input (RM/ha)		
1980 (Initial year)	45	-
2017 (Before change)	931	-
2018 (Beginning of change)	931	931
COBR%		0
2050 (Simulation ends)	931	0
POBR		0
COBR%		-100.0
2018-2050 Absolute change	0	-931
PCOB	0.0	-100.0
e) SSL (%)		
1980 (Initial year)	0.90	-
2017 (Before change)	0.65	-
2018 (Beginning of change)	0.65	0.65
COBR%		0
2050 (Simulation ends)	0.81	0.98
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	0	0
PCOB	24.4	51.0
f) Paddy yield realized per ha per crop (t/ha)		
1980 (Initial year)	2.6	-
2017 (Before change)	4.0	-
2018 (Beginning of change)	4.0	4.0
COBR%		0
2050 (Simulation ends)	7.3	8.0
POBR		1.09
COBR%		9.4
2018-2050 Absolute change	3.3	4.0
PCOB	81.5	98.5
g) Total rice production per year (t/ha/year)		
1980 (Initial year)	1,172,929	-
2017 (Before change)	1,656,664	-
2018 (Beginning of change)	1,666,288	1,666,288
COBR%		0

2050 (Simulation ends)	2,918,697	3,543,430
POBR		1.21
COBR%		21.4
2018-2050 Absolute change	1,252,409	1,877,142
PCOB	75.2	112.7

Notes: POBR is Policy over base run, COBR% is Percentage change over base run, and PCOB is Percentage change over base year
Source: Authors, from model

Key takeaways of this simulation (S7) are:

- This policy simulates the combination of RDE strategies and immediate withdrawal of the input subsidy
- Subsidy withdrawal increases the *Expected variable cost per ha per year* by a quarter but it does not reduce net revenue, yield, production and SSL.
- *Net revenue per ha per year* by one-fifth over BAU figure.
- *Paddy yield realised per ha per crop* increase by about one-tenth, *Total rice production per year* and SSL increase by one-fifth.
- These results point to the dominant roles of the R&D for yield growth, R&D and cropping intensity loops as well as improvement in the extension delay time affecting positively the impacted variables.

3.3 Summary

This section summarises the performance of each of the impacted variables under BAU and the seven simulation runs of S1 to S7. The major indicator variables examined are: *Expected revenue per ha per year, Expected profitability per ha per year (EP), Expected variable cost per ha per year, Net revenue per ha per year, Paddy yield realized per ha per crop, Total rice production per year* and *SSL.* Figures 3.9 – 3.22 indicate the comparison of impacted variables under the BAU and the seven simulations. Each of the variables is discussed individually below.

Expected revenue per ha per year refers to gross revenue to farmers which is calculated by multiplying *Paddy sold per ha per crop* and the *Paddy price* and *Subsidy per unit output sold.* The results conclude the following observations.

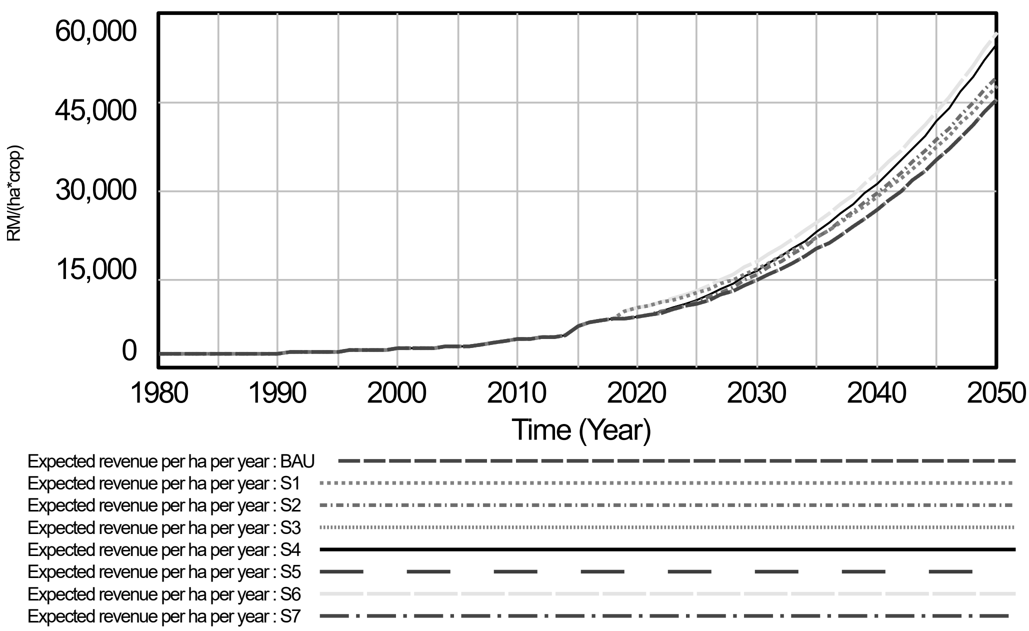
(i) It is apparent that the combination of RDE strategies by themselves or with either subsidy restructuring or input sector development (S4 – S7) give higher *Expected revenue per ha per year* of between RM54,863 to RM56,668. These values are about one-fifth higher compared to S1 to S3 where RDE strategies are not fully exploited.

(ii) Among S4 – S7, the highest expected revenue comes from S6 because of the transfer of input subsidy to the output with POBR of 1.25.

(iii) Among S1 – S3, S2 (subsidy withdrawal and yield improvement combination) gives the highest *Expected revenue per ha per year* figure.

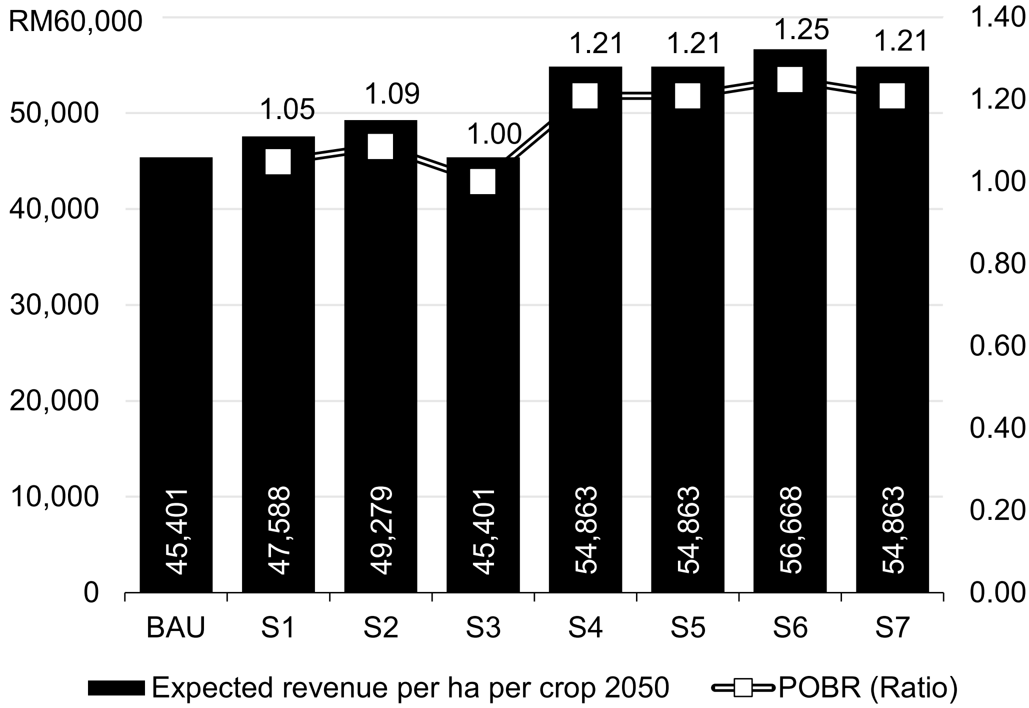
(iv) The lowest *Expected revenue per ha per year* is produced by S3 ie continuous increase in input subsidy.

Figure 3.9 Comparison of Expected Revenue per ha per year under BAU and All Simulations (RM/ha/year), 1980 – 2050



Source: Authors, from model

Figure 3.10 Expected Revenue per ha per year (RM/ha/year) and POBR (Ratio) under BAU and All Simulations, 2050



Note: POBR is ratio of results from simulation over base run in 2050
Source: Authors, from model

Expected profitability per ha per year (EP). As defined earlier this variable is basically a mark-up ratio. The behaviour of this variable is shown in Figure 3.11 and 12. The simulations show the following observations:

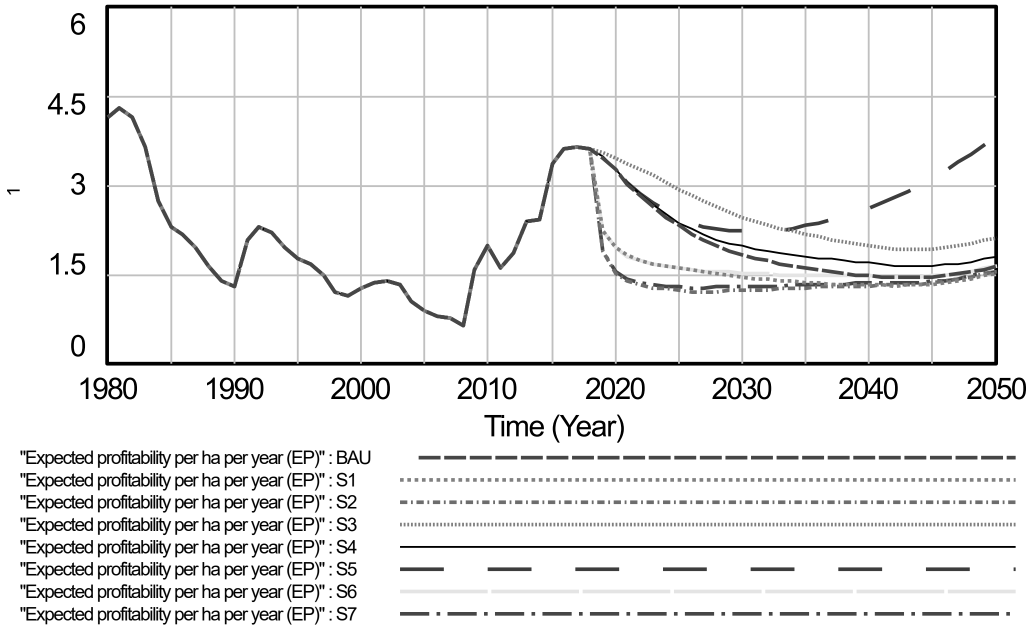
(i) S3 to S7 give higher *Expected profitability per ha per year (EP)* above the BAU value.

(ii) Among S5 – S7, the highest *Expected profitability per ha per year (EP)* comes from S5 because the development in input sector reduces *Expected variable cost per ha per year* which improves revenue. S5 indicates the highest POBR of 2.35.

(iii) Among S1 – S4, S3 (continuous increase in input subsidy) gives the highest *Expected profitability per ha per year (EP)* as it helps to reduce *Expected variable cost per ha per year.*

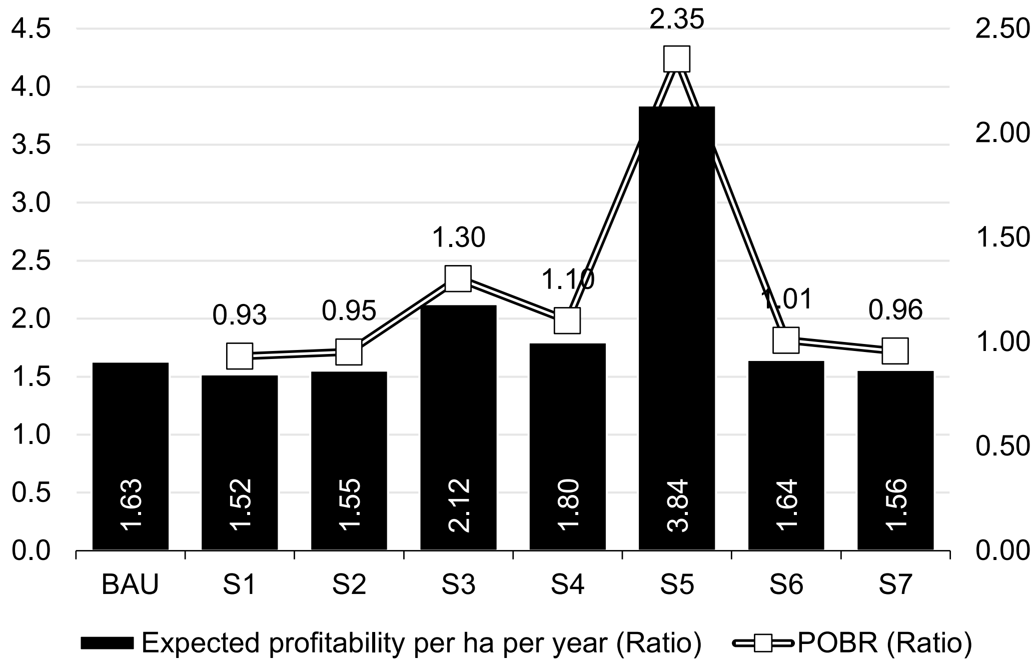
(iv) The lowest *Expected profitability per ha per year (EP)* comes from S1 where input subsidy is transferred to output.

Figure 3.11 Comparison of Expected Profitability per ha per year (EP) under BAU and All Simulations (RM/ha/year), 1980 – 2050



Source: Authors, from model

Figure 3.12 Expected Profitability per ha per year (EP) and POBR under BAU and All Simulations (Ratio), 2050



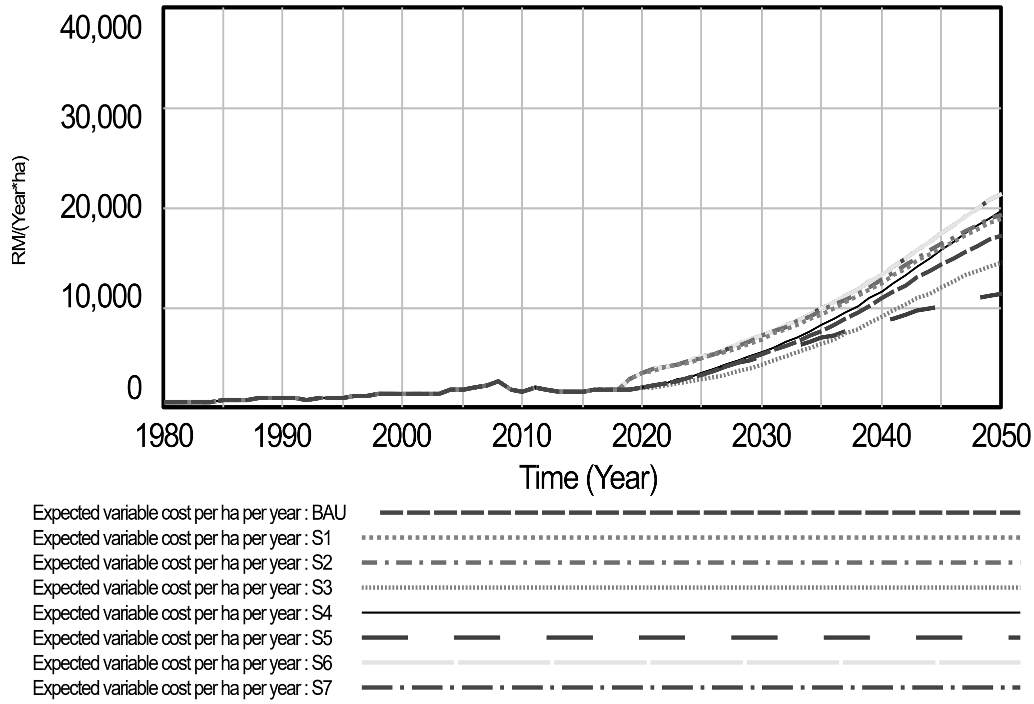
Note: POBR is ratio of results from simulation over base run in 2050
Source: Authors, from model

Expected Variable cost per ha per year refers to both *Expected NL input cost per ha per crop* and *Expected labour cost per ha per crop*. The simulations point to the following observations:

(i) S3 (continuous increase in input subsidy) and S5 (RDE strategies and input sector development) give the lowest *Expected variable cost per ha per year* at RM14,531 and RM11,331 respectively.

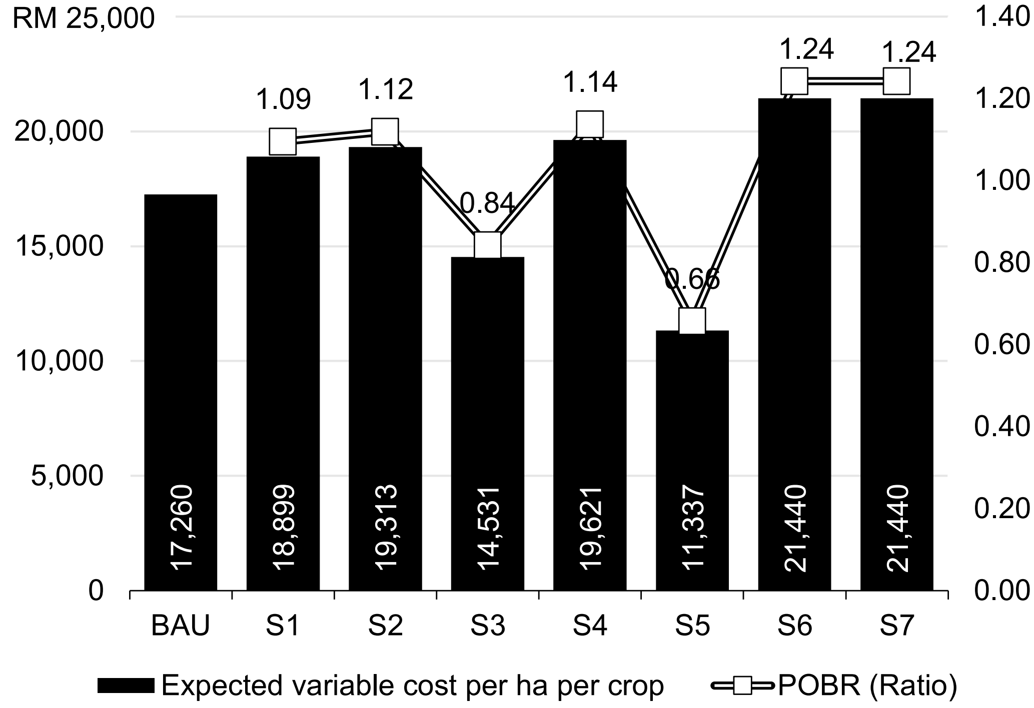
(ii) S6 and S7 produce the highest *Expected variable cost per ha per year* at RM21,440 due to the increase in *Paddy planted area* with an increase in *Cropping intensity*.

Figure 3.13 Comparison of Expected Variable Cost per ha per year and POBR under BAU and All Simulations (RM/ha/year), 1980 – 2050



Source: Authors, from model

Figure 3.14 Expected Variable cost per ha per year (RM/ha/year) and POBR (Ratio) under BAU and All Simulations, 2050



Note: POBR is ratio of results from simulation over base run in 2050
Source: Authors, from model

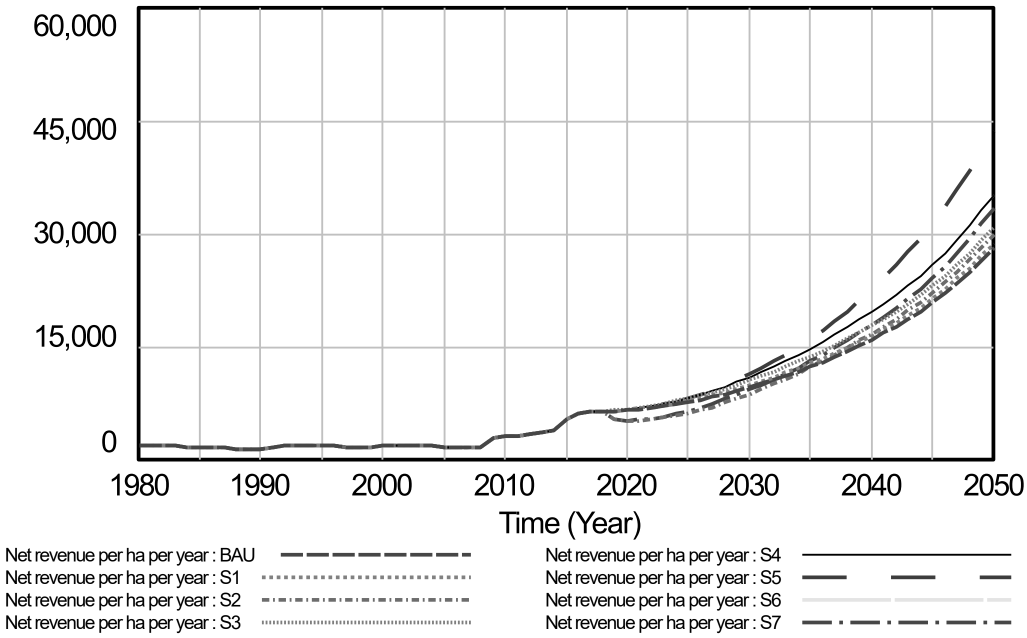
Net revenue per ha per year is the difference between *Expected revenue per ha per year* and *Expected variable cost per ha per year* (Fig. 3.15 and 16). The simulations conclude the following observations:

(i) The combination of RDE strategies under S4 – S7 gives the highest *Net revenue per ha per year* of between RM33,423 to RM43,526. The *Net revenue per ha per year* is about one-fifth higher than those under S1 – S3.

(ii) The highest *Net revenue per ha per year* (RM43,526) comes from S5 (a combination of RDE strategies and input development).

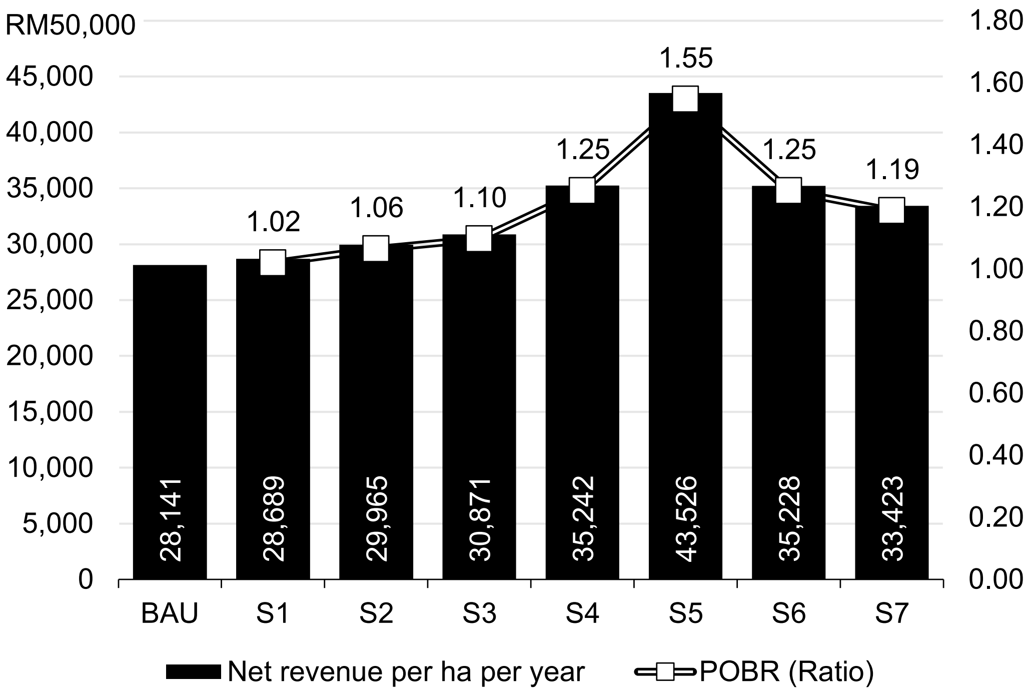
(iii) S1 to S4 produce lower *Net revenue per ha per year* within the range of RM28,689 to RM30,871. The lowest *Net revenue per ha per year* comes from S1 (subsidy transfer).

Figure 3.15 Comparison of Net Revenue per ha per year under BAU and All Simulations (RM/ha/year), 1980 – 2050



Source: Authors, from model

Figure 3.16 Net revenue per ha per year (RM/ha/year) and POBR (Ratio) under BAU and All Simulations, 2050



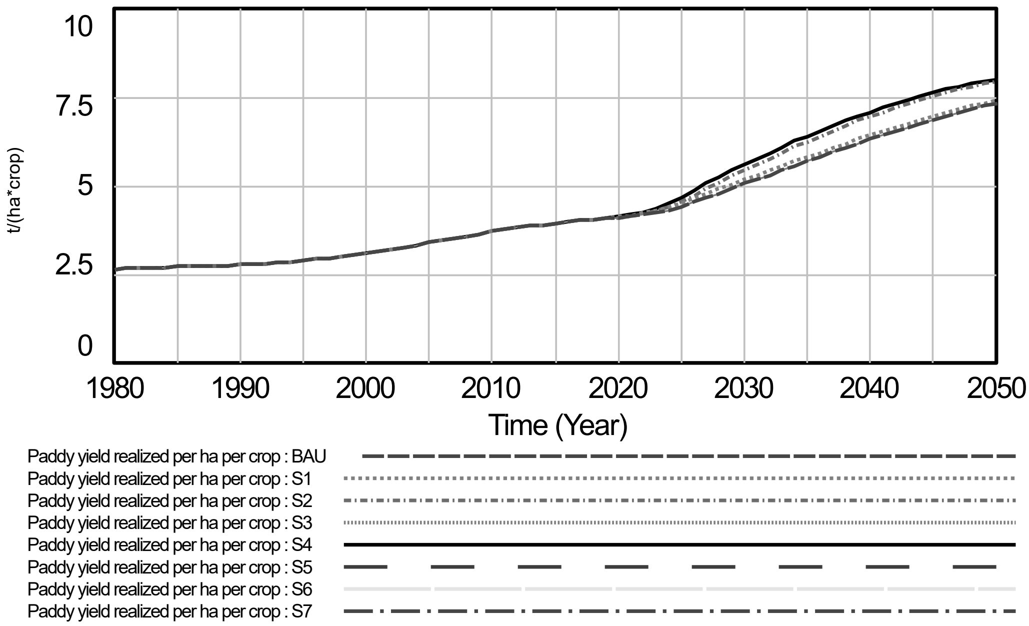
Note: POBR is ratio of results from simulation over base run in 2050
Source: Authors, from model

Paddy yield realised per ha per crop. The simulations on this variable (Figures 3.17 and 18) conclude the following observations.

(i) The various combinations of RDE strategies with subsidy restructuring and input development under S4 – S7 produce high *Paddy yield realised per ha per crop* at 8 t/ha/crop in 2050 with POBR ratio of 1.09.

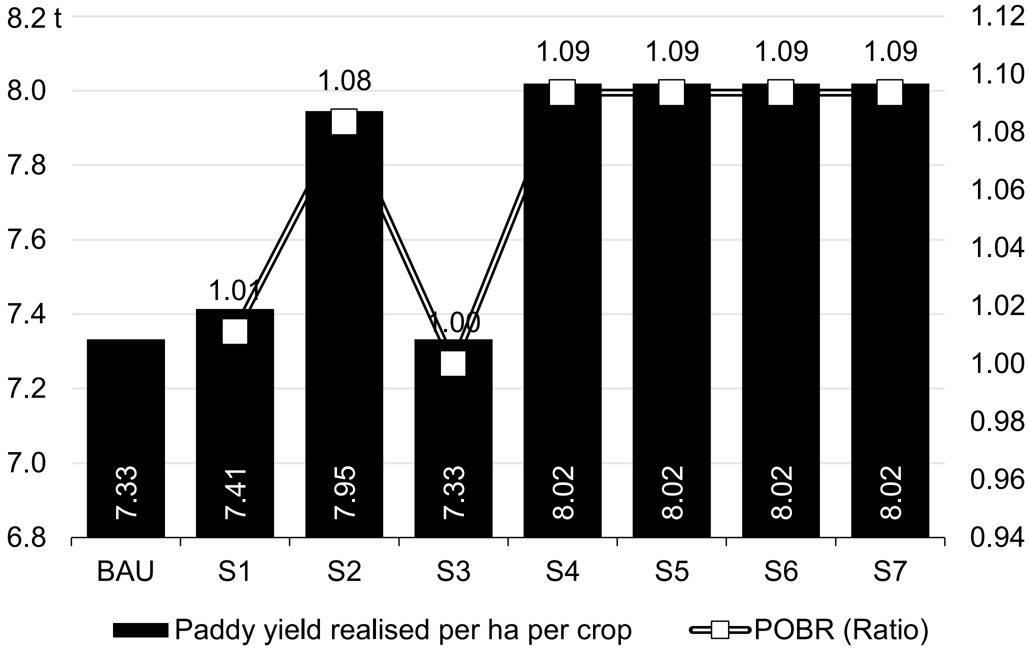
(ii) S3 (continuous increase in input subsidy) fails to increase the *Paddy yield realised per ha per crop* beyond the level achieved under BAU. The POBR for S3 is 1 while it is 1.01 and 1.08 for S1 and S2 respectively.

Figure 3.17 Comparison of Paddy Yield Realised per ha per crop under BAU and All Simulations (t/ha/crop), 1980 – 2050



Source: Authors, from model

Figure 3.18 Paddy yield realised per ha per crop (t/ha/crop) and POBR (Ratio) under BAU and All Simulations, 2050



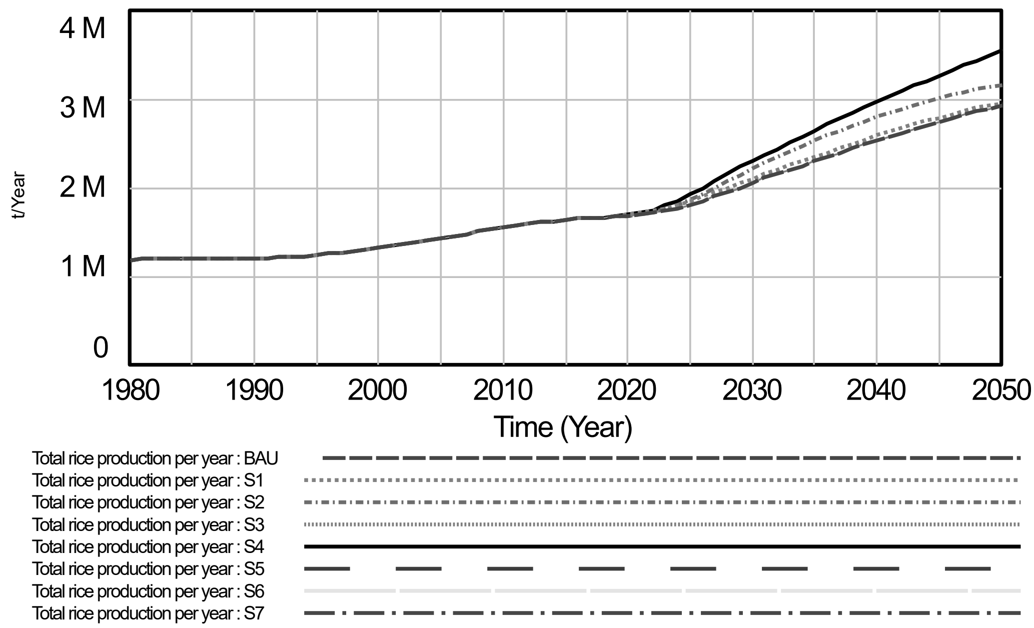
Note: POBR is ratio of results from simulation over base run in 2050
Source: Authors, from model

Total rice production per year. As shown in Fig. 3.19, the behaviour of the *Total rice production per year* emulates the behaviour shown under *Paddy yield realised per ha per crop* above as *Total rice production per year* is derived from *Paddy planted area* multiply by yield.

(i) The various combinations of RDE strategies with subsidy restructuring and input development under S4 – S7 give higher *Total rice production per year* figure of 3.5m t/year in 2050 with POBR ratio of 1.21 for all the simulations.

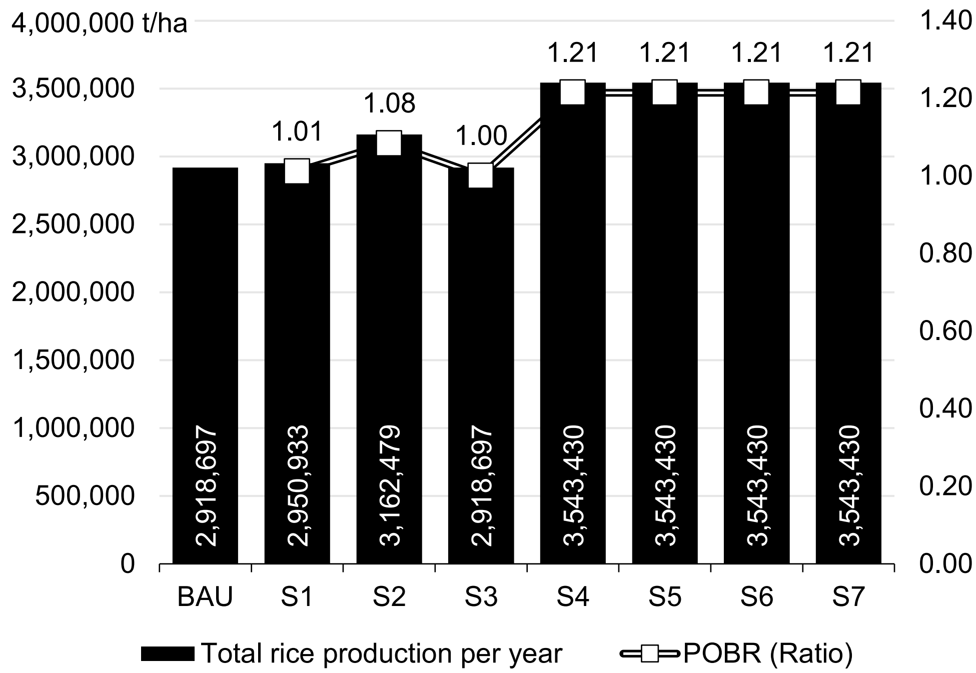
(ii) S1 to S3 yield lower *Total rice production per year* figure in the range of 2.9m to 3.2m t/year. The lowest *Total rice production per year* figure comes from S3 (continuous increase in input subsidy).

Figure 3.19 Comparison of Total Rice Production per year under BAU and All Simulations (t/year), 1980 – 2050



Source: Authors, from model

Figure 3.20 Total Rice Production per year (t/year) and POBR (Ratio) under BAU and All Simulations, 2050



Note: POBR is ratio of results from simulation over base run in 2050

Source: Authors, from model

Self-sufficiency level (SSL) is defined as the ratio of production over the *Rice requirement*. As shown in Figure 3.21, the behaviour of the *SSL* emulates behaviour shown under *Paddy yield realised per ha per crop* and production as the denominator (rice requirement) is the same for all simulations.

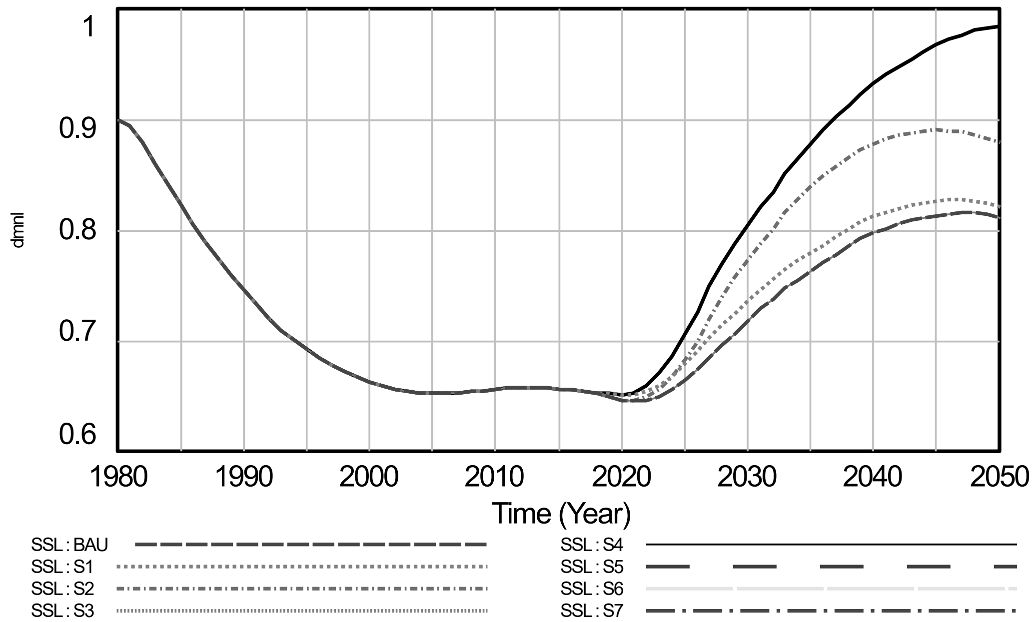
(i) The various combinations of RDE strategies with subsidy restructuring and input development under S4 – S7 give a higher level of *SSL* at 98% with POBR ratio of 1.21 for these simulations.

(ii) S1 to S3 yield lower SSL figure in the range of 81% to 88% with POBR ratio of 1 to 1.08.

(iii) Among S1 – S3, S2 (withdrawal of subsidy and improvement in yield) give the highest *SSL* at 88% with POBR ratio of 1.08.

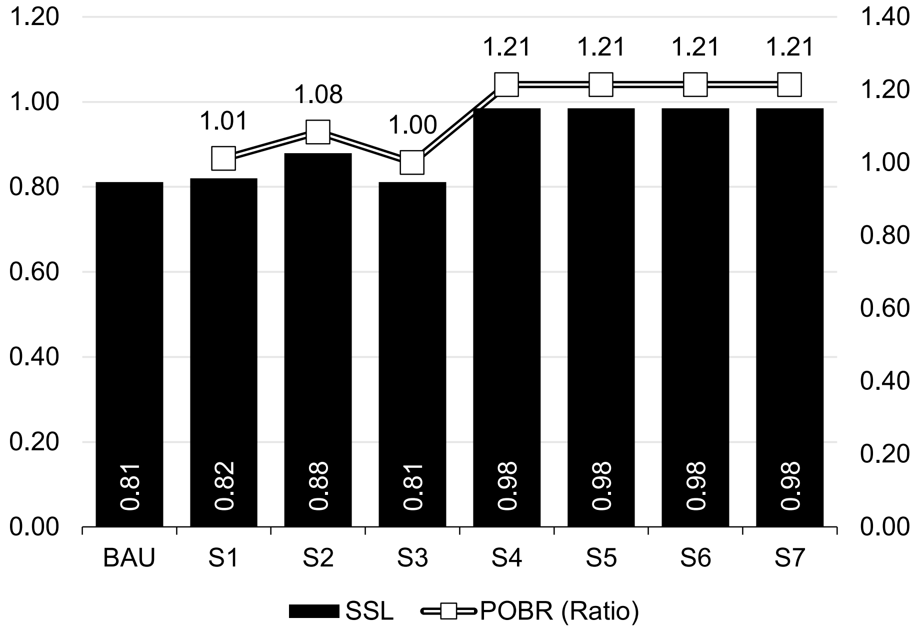
(iv) The lowest *SSL* comes from S3 (continuous increase in input subsidy) which fails to increase the *SSL* beyond the BAU value of 81%.

Figure 3.21 Comparison of Self-sufficiency Level under BAU and all Simulations (%), 1980 – 2050



Source: Authors, from model

Figure 3.22 Self-sufficiency Level and POBR under BAU and All Simulations (Ratio), 2050



Note: POBR is ratio of results from simulation over base run in 2050
Source: Authors, from model

Table 3.10 summarises the results of the BAU and seven simulation runs on the above selected impacted variables. Variables that achieve high PBOR ratios are highlighted. The results point to the following conclusions.

(i) The simulations that give high values of POBR ratios are found under combined simulations of S4 to S7. S4 refers to three RDE strategies while the rest are combinations of RDE strategies with local input development (S5), transfer of input subsidy to output (S6) and immediate withdrawal of input subsidy (S7).

(ii) Single simulation (S3) and double combination (S1 and S2) are incapable to produce results that are significantly higher than the BAU runs.

(iii) S5 is the most effective as it produces the highest impact. S5 (a combination of RDE and development of local input sector) produce the highest number of high POBR ratios. For instance, it gives POBR ratio of 2.35 for *Expected profitability per ha per year (EP), Net revenue per ha per year* (1.5), *Paddy yield realised per ha per crop* (1.09), *Total rice production per year* (1.21), *SSL* (1.21) the lowest *of Expected variable cost per ha per year* (0.66).

(iv) Single policy simulation run such as in S3 (continuous increase in input subsidy) fails to achieve improvement in all the impact variables.

(v) The hypothesis that a continuous increase in subsidy may reduce cost and hence increase the producers' revenue proves otherwise as other institutional supports are required to increase revenue.

Table 3.10 Comparison of Policy Simulations on Selected Variables by Selected Years

Variable	Year	BAU	S1	S2	S3	S4	S5	S6	S7
Expected revenue per ha per year (RM/ha/year)	1980	2,218	2,218	2,218	2,218	2,218	2,218	2,218	2,218
	2018	8,144	8,144	8,144	8,144	8,144	8,144	8,144	8,144
	2050	45,401	47,588	49,279	45,401	54,863	54,863	56,668	54,863
	POBR		1.05	1.09	1.00	1.21	1.21	1.25	1.21
Expected profitability per ha per year (EP) (Ratio)	1980	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
	2018	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
	2050	1.63	1.52	1.55	2.12	1.80	3.84	1.64	1.56
	POBR		0.93	0.95	1.30	1.10	2.35	1.01	0.96
Expected variable cost per ha per year (RM/ha/year)	1980	431	431	431	431	431	431	431	431
	2018	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770
	2050	17,260	18,899	19,313	14,531	19,621	11,337	21,440	21,440
	POBR		1.09	1.12	0.84	1.14	0.66	1.24	1.24
Net revenue per ha per year (RM/ha/year)	1980	1,788	1,788	1,788	1,788	1,788	1,788	1,788	1,788
	2018	6,374	6,374	6,374	6,374	6,374	6,374	6,374	6,374
	2050	28,141	28,689	29,965	30,871	35,242	43,526	35,228	33,423
	POBR		1.02	1.06	1.10	1.25	1.55	1.25	1.19
Paddy yield realised per ha per crop (t/ha/crop)	1980	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62
	2018	4.04	4.04	4.04	4.04	4.04	4.04	4.04	4.04
	2050	7.33	7.41	7.95	7.33	8.02	8.02	8.02	8.02
	POBR		1.01	1.08	1.00	1.09	1.09	1.09	1.09
Total rice production per year (t/year)	1980	1,172,929	1,172,929	1,172,929	1,172,929	1,172,929	1,172,929	1,172,929	1,172,929
	2018	1,666,288	1,666,288	1,666,288	1,666,288	1,666,288	1,666,288	1,666,288	1,666,288
	2050	2,918,697	2,950,933	3,162,479	2,918,697	3,543,430	3,543,430	3,543,430	3,543,430
	POBR		1.01	1.08	1.00	1.21	1.21	1.21	1.21
SSL (%)	1980	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	2018	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	2050	0.81	0.82	0.88	0.81	0.98	0.98	0.98	0.98
	POBR		1.01	1.08	1.00	1.21	1.21	1.21	1.21

Note: POBR is ratio of results from simulation over base run in 2050.
Source: Authors, from model

Table 3.11 Ranking of Policy Simulations

Variable	Ranking of Simulation						
	1st	2nd	3rd	4th	5th	6th	7th
Expected revenue per ha per year (RM/ha/year)	S6	S4, S5, S7	S2	S1	S3	..	..
Expected profitability per ha per year (RM/ha/year)	S5	S3	S4	S6	S7	S2	S1
Expected variable cost per ha per year (RM/ha/year)	S5	S3	S1	S2	S4	S6, S7	..
Net revenue per ha per year (RM/ha/year)	S5	S4	S6	S7	S3	S2	S1
Paddy yield realised per ha per crop (t/ha/crop)	S4 - S7	S2	S1	S3	..	..	..
Total rice production per year (t/year)	S4 - S7	S2	S1	S3	..	..	..
SSL (%)	S4 - S7	S2	S1	S3	..	..	..

In terms of ranking, it is clear that S5 is the most effective policy mix as it ranked the first for six impact variables (Table 2). S5 gives the highest value for expected profit, net revenue, yield, rice production and SSL and the lowest variable cost. S6 provides the highest value for four impact variables; namely expected revenue, yield, rice production and SSL. S4 - S7 ranked first for yield, rice production and SSL. S3 ranked the lowest for expected revenue, yield, rice production and SSL. In short, the most effective strategies are the mixes of RDE and local input sector development (S5) and transfer of input to output (S6). The least effective strategy is S3 (continuous increase in input subsidy).

4

CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The study seeks to examine how institutional factors have shaped the structure and behaviour of the paddy and rice industry and hence impacted its performance. In view of its strategic importance for food security purpose, the industry is highly protected and insulated from external challenges. Some of the interventionist instruments implemented include; Guaranteed Minimum Price (farm floor price), provision of input and output subsidies and investment on R&D and extension, among others. Despite these interventions and large budgetary allocation of subsidies, the industry fails to indicate progressive growth in yield, SSL and improvement in the producers' income. Clearly, those institutional supports are in need of revisions. Towards that end, the study has simulated seven policy combinations of subsidy restructuring, RDE strategies in improving extension, yield and cropping intensity, and development of local input sector. The findings point to these following conclusions.

The lacklustre yield growth and low net revenue to farmers are the results of an eco-system where the R&D and extension sub-system is not fully energised to bring maximum impact on important variables such as farmer revenue, yield, production and SSL. The poor performance of S1 to S3 supports this statement. The failure of S1 to S3 in bringing out significant impact is due to the strong dominance of the other RDE loops not taken into account in the simulation particularly R&D and crop intensity loop. Without the full complementation of the RDE strategies, subsidy restructuring alone or weak combination of RDE strategies and the latter, will not create significant improvement to the system. In short, to obtain full impact, the complete package of RDE is deemed necessary.

The full activation of RDE functions in expediting extension service, improving yield and cropping intensity combined with subsidy restructuring or input sector development (S4-S7) bring significant improvement to the whole system. As shown in the ranking table, S4-S7 give the most impact on yield, production, SSL and farmer revenue.

A single policy of continuous increase in input subsidy (S3) and a weak combination of RDE strategy and subsidy restructuring (S1 and S2) are ineffective in impact. This is proven in the poor performance of S1 to S3 which manages to increase farmer revenue but fail to bring significant improvement on yield, production and SSL.

The 40-year old input subsidy is not indispensable. Even when input subsidy is totally withdrawn immediately, a fully functioning RDE in the three said functions (S7) is effective enough to energize the whole system towards higher yield, production, SSL and farmer revenue. This simulation proves that input subsidy is dispensable provided that growth inducers are injected particularly RDE's full functions.

The combination of RDE strategies and development of local input sector (S5) yields the highest return as it addresses fully the two major challenges in paddy production i.e., low yield and high variable cost. For instance, it produces the highest *Net revenue per ha per year* of RM43,526, *Paddy yield realized per ha per crop* of 8 t/ha/crop, *Total rice production per year* of 3.5m t/year, SSL of 98% and the lowest cost of production, 34% lower than the BAU run in 2050. In fact, S6 achieves high POBR scores in all the impacted variables. This policy mix is ideal as it addresses the fundamental problems of the industry i.e., low yield and high input cost. This simulation indicates a systems approach in addressing the fundamental problems brings greater impact to the sector.

These simulations (S4 – S7) support the thesis that R&D is the source of growth for food production. In fact, FAO (2009) stated that as for future food production, 80% of the necessary production increases would come from increases in yields and cropping intensity and only 20% from expansion of arable land[81]. After a long stagnation, the paddy and rice industry need to be re-energised by enhancing growth inducer through RDE in the areas of extension, yield improvement and cropping intensity, and development of local input sector.

In short, the vicious circle of slow growth of the paddy and rice sector is not unbreakable, a new virtuous circle can be created. The simulations prove that subsidy is not the panacea to growth and sustainability. Based on the findings, the proposed eco-system of the new virtuous circle comprises an optimum complementarity of RDE strategies, productive subsidies and incentive and local input development. These entail: energising the RDE sub-system to enhance yield, cropping intensity and extension effectiveness, provision of productive incentives for efficient use of input (land, labour, non-labour input and capital) and actualise local input production to ensure the sustenance of the paddy and rice sector.

4.2 Recommendations

The study proposes a virtuous cycle to break the current vicious circle of slow growth of productivity, production of paddy and rice and low return to paddy producers. The following are proposals based on the findings of the study.

(i) Institutional supports:

a. Reduce the gap between potential and realised yield through effective extension services and participatory research involving researcher, farmer and extension agent.

b. Intensify R&D for high yielding varieties.

c. Expedite R&D to increase cropping intensity.

81 FAO (2009)

(ii) Subsidies and incentives

Rationalization of subsidies with emphasis of output-based and productive subsidies and incentives with full supports from the R&D and extension services. Productive subsidies and incentives include those that encourage production efficiency or farm innovations (machines, gadgets, paddy-based products such as fertiliser and other value added products).

(iii) Input sector development

Development of local input sector; organic fertiliser, pesticides, small machines for small farms and ICT and IOT applications.

(iv) Systems thinking-based policy

Policy strategies must take into account the eco-system of the industry and the behaviour of its elements and market participants (producer, traders, millers and consumers).

(v) Evidence-based decision making

Modelling guides policy makers to understand relationship between elements in the system, its behaviour and performance. Policy modelling is needed to guide the policy makers and implementers in identifying the optimal strategies, their impact, trade-offs and long term implications.

4.3 Future Research

Like other studies, this research has its own limitations. They are mainly related to the inadequacies in:

(i) Empirical evidence on the relationships between input and output of paddy production particularly the impact of fertiliser, labour, technology on productivity.

(ii) Empirical evidence on the relationships between institutional policy and supports such as R&D allocation and capacity, investments on infrastructure, extension services and market interventions on productivity and growth.

(iii) Base line information on the local-made input production and industry.

(iv) Evidence on factors that determine farmer's decision making.

(v) Cost and efficiency of imported machines for farm activities.

Based on the above limitations and findings of the study, suggestions on future research include the following areas:

(i) Relationship between input and productivity.

(ii) Farmer decision making process particularly input usage (labour and non-labour input) and marketing decision.

(iii) Impact of government policies on the sector (pricing, subsidies, infrastructure, centralization of input distribution and import monopoly) on productivity and growth.

(iv) The prospect and feasibility of development of local input sector comprises fertilizer, pesticides, local machines for small farms, ICT/IOT applications to improve efficiency and returns.

(v) Structure and performance of the rice milling sector.

(vi) Impact of government policies on the sector (pricing, subsidies, infrastructure, centralization of input distribution and import monopoly) on productivity and growth.

(vii) Development of precision and sustainable paddy farming.

(viii) Improvement in farm institutions (cooperatives and farmers associations) to help farmers improve their bargaining power, self-reliance and hence returns.

(ix) R&D on crop-mix or multi-enterprise farming to conserve soil fertility and improve farmers' returns.

(x) Prospect of producer's involvement in value added activities as well as input distribution through cooperatives or farmers' association to enhance returns.

(xi) Development of regional models, especially for granary and non-granary areas, due to obvious differences in terms of infrastructure, institutional support, and behavioural characteristics of farmers involved.

APPENDIX 1: Overview of Paddy and Rice Sector

Table A1 Overview of Paddy and Rice Sector

Item	1970	1980	1990	2000	2015
Population (‘000) [1/]	10,882	13,879	18,102	23,495	30,598
GDP at current price (RM m) [2/]	11,829	53,308	119,081	356,401	1,157,723
GDP per cap. at current price (RM) [3/]	1,087	3,841	6,578	15,169	37,123
Agricultural GDP (%)	30.8	22.2	16.3	8.9	8.9
Paddy/Total GDP (%) [4/]	na	0.72	0.52	0.16	0.002
Paddy/Agric. GDP (%)	na	4.70	4.8	2.9	0.2
Agri. dev. expenditure (RM m) [5/]	1,194	7,671.0	8,215.0	7,860.0	11,435.0
Irrigation dev. Expend. (%) [6/]	31	5.2	10.3	27.6	12.8
Total agric. Land (‘000 ha) [7/]	3,445	4,468	5,480	5,949	7,380
Paddy area (‘000 ha) [8/]	704.7	716.8	680.6	698.7	730.0
Paddy area (%)	20.5	16.0	12.4	11.7	9.9
Granary paddy area (‘000 ha) [9/]		317.0	494.0	518.0	441.1
Granary paddy area (%)		44.2	72.6	74.1	60.4
Production of paddy (‘000 t) [10/]	1,681.4	2,044.6	1,895.0	2,140.9	3,322.0
Production of rice ('000 t)	1,059.3	1,318.3	1,215.1	1,381.7	2,159.3
Production of paddy from granary area(‘000 t) [11/]			1,297.7	1,366	2,277
Production of paddy from granary area (%)		-	68.5	63.8	68.5
Yield (t/ha) [12/]	1.8	2.85	2.77	3.06	4.55
Yield in granary area (t/ha)		4.08	3.47	3.75	5.47
Average farm size (ha) [13/]	1.2	1.60			2.00
Import of rice (‘000 t) [24/]	355	167.6	330.3	595.6	960.8
Consumption of rice ('000 t)	1,415	1,485	1,632	1,978	3,120
Consumption of rice (kg/cap) [15/]	128	105	90	85	88
SSL (%)	0.75	0.89	0.74	0.70	0.69
Guaranteed minimum price (RM/t) [16/]	264	496	550	550	1,200
Wholesale price of rice (RM/t)	455.00	782.22	878.33	1,105.33	2,150.00
Retail price of rice (RM/t)	563	841	917	1,190	2,600
Paddy price subsidies (RM m) [17/]	not provided	88	359	406	480
Input subsidies (all types) (RM m)	na	151	142	405	1,731
Total subsidies (RM m)		239	501	811	2,211
Rice price (border) (RM/t) [18/]	455	1,027	812	1,190	1,731
Share of LPN/Bernas in buying of paddy (%) [19/]	0.6	36	49.0	36	34
Agricultural labour (‘000) [20/]	na	1,636	1,738	1,552	1,754

No. of paddy farmers [21/]	140,000 (PM)	416,000	108,400 (PM)	314,158	197,189
Poverty among farmers (%) [22/]	88.1	58	48.3	na	na
No. of mills [23/]	1974=964	na	1987=329	2000=251	157
Monthly expenditure per household (rice) (RM/mth) [24/]	1993/4 (28)	1998/9 (39)	2004/5 (36)	2009/10 (42)	2014 (42)
RM/month [25/]	28	39	36	42	42

1/ http://epu.gov.my/ms/statistik-ekonomi/kependudukan-tenaga-buruh

2/ http://epu.gov.my/ms/statistik-ekonomi/akaun-negara

3/ https://www.dosm.gov.my/v1/uploads/files/3_Time%20Series/Malaysia_Time_Series_2015/01_Akaun_Negara.pdf

4/ http://epu.gov.my/ms/statistik-ekonomi/akaun-negara

5/ MardiTech (2003). Data for 2015 is from the year 2010 from Ninth Malaysia Plan (2006-2010)

6/ MardiTech (2003). Data for 2015 is from the year 2010 from Ninth Malaysia Plan (2006-2010)

7/ Five Malaysia Plans (various issues on land use)

8/ Data for 1970 is from FAOStat.org, data for 1980, 1990, 2000 from https://www.dosm.gov.my/v1/uploads/files/3_Time%20Series/Malaysia_Time_Series_2015/09Padi.pdf and data for 2015 from DoSM (2017) Indikator Pertanian Terpilih

9/ Data for 1990 and 2000 are from Marditech (2003), Data from 2015 is from Min. of Agric. And Agro-based Industries (2016)

10/ Data for 1970 is from FAOStat.org, Data from 1980, 1990 and 2000 are from https://www.dosm.gov.my/v1/uploads/files/3_Time%20Series/Malaysia_Time_Series_2015/09Padi.pdf. and Data for 2015 from DOSM (2017). Indikator Pertanian Terpilih

11/ Data for 1990 and 2000 are from Marditech (2003), Data from 2015 is from Min. of Agric. And Agro-based Industries (2016)

12/ https://www.dosm.gov.my/v1/uploads/files/3_Time%20Series/Malaysia_Time_Series_2015/09Padi.pdf and data for 2015 from Miin. Of Agric. Agro-based Industries (2016)

13/ 1.2 1.2 ha in 1970 (Selvadurai, 1972), 1988 average 1.6 ha World Bank 1988, 2015 IPB MoA

14/ FAOStat.org

15/ Data f0r 1970, 1980, 1990, 2000 are from MARDITech (2003), Data for column 2015 is from 2014 from MoA (2015) Paddy Statistics, 2014

16/ Data for 1970 and 1980 is from Fatimah (et al., 1984), 1990 and 2000 from Marditech (2003), 2015 from MoA

17/ Data for 1980 and 1990 from MardiTech (2013), 2000 and 2015 are from MoA (2016).

18/ Data for 1970 is from World Bank (1984), the rest are from www.imf.org

19/ Data 1970, 1980 and 1990 are from Annual Reports of National Paddy and Rice Authority, data for column 2000 is for 2007 is from MIER (2010), column 2015 is for 2011 from http://ageconsearch.umn.edu/bitstream/100726/2/Vengedasalam.pdf.

20/ https://www.dosm.gov.my/v1/uploads/files/3_Time%20Series/Malaysia_Time_Series_2015/Penerbitan_Siri_Masa_2015.pdf

21/ Data for 1980 was from Marditech (2003). The rest are from MoA (2016). Note that PM is for Peninsular Malaysia.

22/ Five Year Malaysia Plan (various years)

23/ 1. Persatuan Pengilang Beras Melayu Malaysia (2015). 2 and 3 from Tan Siew

24/ DOS, Household Expenditure Survey, various years

25/ DOS, Household Expenditure Survey, various years

APPENDIX 2: Introduction to System Dynamics

System Dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems–literally any dynamic system characterized by interdependence, mutual interaction, information feedback, and circular causality[82].

System dynamics modelling paradigm finds its roots in Control Engineering, a discipline that analyses dynamic systems by summarising them as systems of difference and differential equations[83]. It was originally developed as a tool to study complex systems[84] through the concept of stocks, flows, feedbacks and delays, which are mathematically formalised along with parameters and relationships in a system of equations. The main advantage of using system dynamics is its macro-level perspective in the analysis of systems because, when modelling, it treats the part of the real-world subject of the analysis as an undifferentiated whole[85]. The properties of the target system that can be described with system dynamics models are its whole state and its variations: the former is represented with state variables in the form of 'levels', whereas the latter is represented with 'rates'[86].

Since any given variable of the system can change as its value depends on the behaviour of the other variables, system dynamics contemplates nonlinear interaction. Nonetheless, this modelling paradigm does not allow the modelling of heterogeneous aspects of the system's behaviours. This is because the hypothesis on which it grounds is that "the system behaviour is the result of circular and time-delayed relationships between structural components, factors or variables[87] and thus requires full *ex-ante knowledge and description of the system's structures*[88].

The Performance of Using System Dynamics

System dynamics is popularised with 'Limits to Growth'. It is a summary of the results from a computer modelling (e. g. Dynamo, Stella, PowerSim, Vensim, iThink) exercise concerned with the future development of the world economy. The model uses the relationship among the major variables like population, pollution, resources, capital and land, and it is purported to show the outcome of the relationship between the variables for the next 50 to 100 years[89].

82 System Dynamics Society (2017)
83 Forrester (1980)
84 Forrester (1961)
85 Brauer & Castillo-Chavez (2001)
86 Gilbert & Troitzsch (2005)
87 Squazzoni (2012)
88 Randers (1980), Hanneman & Patrick (1997), Gilbert & Troitzsch (2005), and Grьne-Yanoff & Weirich (2010)
89 Forrester (1971), and Meadows (1980).

One of the uniqueness of using system dynamics is that, it is used to investigate a complex dynamic problems in terms of stocks (the accumulation of things), flows (the motion of things) and feedback loops at any level of aggregation[90].

Furthermore, it can be used with what are thought to be 'data poor' problems. This is because, the information base for the conceptualisation and formulation of system dynamics models are much broader than the numerical database. The model is employed in operations research and statistical modelling - numerical data from the written database (reports, operations manuals, etc.), and the expert knowledge of the field)[91].

This method can be useful to gain insight and understanding in a messy situation by sketching increasingly sophisticated causal loop diagrams[92]. It does not need one who are good in statistics to use system dynamics. Enough with just a simple algebra[93].

Problems and Limitations of System Dynamics

One of the main drawbacks of using system dynamics is that the model can be over-elaborated. In general, both the philosophy and the general-understanding purpose of the system dynamics modelling require simplicity and transparency[94].

Like other modelling techniques but less bothersome, are estimation of parameters, sensitivity testing and assessment of model validity. Statistical estimation procedures are seldom used in system dynamics for four reasons.

Firstly, system dynamics models are not directed to problems of detailed implementation or precise prediction, but to problems of general understanding that do not need a high accuracy numbers. Secondly, the long-term nature of most system dynamics problem statements, parameters are likely to exceed historic ranges, therefore estimation based on historic data alone would be insufficient. Thirdly, the nonlinear feedback structure of the models makes standard statistical techniques either not applicable or extremely difficult. And finally, the nonlinear feedback structure of system dynamics models reduces the sensitivity to precisely refine the parameter values[95].

The general insensitivity of system dynamics models are partially determined by their feedback structure, but also due to the way sensitivity is defined in the system dynamics paradigm. The model output is not read as quantitative predictions (particular variables in particular years) but for qualitative behavioural characteristics. In system dynamics, a model is said to be sensitive to a given parameter when there is a change in the numerical value of the parameter which gives change to the entire behaviour of the model[96]. This particular sensitive parameter is crucial as one that must be estimated carefully or that might be one that be an effective site for policy input. And no rigorous theory or procedure exists in

90 Sterman (2000)
91 Sharp et al, (1983), and Morecroft (2015).
92 Bassi (2013)
93 Sterman (2000)
94 Meadows (1980), Vazquez et al. (1996), Sterman (2000), and Morecroft (2015).
95 Meadows (1980) and Sterman (2000).
96 Forrester (1971), Meadows et al. (1972), and Meadows (1980).

system dynamics for performing sensitivity analysis and this is a weakness of the field[97].

When it comes to model validity, system dynamics paradigm handles the problem qualitatively and informally. There is no precise, quantitative index to summarise the validity of system dynamics model. According to Forrester (1971) and Meadows (1980), one way to validate a system dynamics model is when it meets the following conditions[98]:

(i) Every element and relationship in the model reflects a real-world situation and is consistent with whatever measurements or observations are available.

(ii) When the model is used to simulate historical periods, every variable exhibits the qualitative, and roughly quantitative, behaviour that was observed in the real system.

(iii) When the model is simulated under extreme conditions, the models system operation is reasonable (physical quantities do not become negative or exceed feasible bounds).

One of major problems in system dynamics is that, it leads the analyst naturally to a long-time horizon and wide-boundary approach to any problem. This is not usually consistent with the very real short-term pressures or constraints felt by decision makers[99].

The Process in Developing System Dynamics Model

The structure of the system dynamics model is determined by the concept from written literature, purpose, and mental and written information. The structure is connected using the principle of feedback loops to form a model. After the model is formed, the behaviour from the model and real-world behaviour (based on historical data) are compared. If discrepancies between the model and real-world exist, the model needs to be improved in terms of its structure and also parameters. Then, it can be used for policy evaluation and also to make policy alternatives.

There are five steps that involved in approaching a problem from the system dynamics perspective[100]. The steps are as follows:

1) Problem articulation;
2) Formulation of dynamic hypothesis;
3) Formulation of a simulation model;
4) Testing; *and*
5) Policy design and evaluation.

97 Meadows (1980)
98 Forrester (1971) and Meadows (1980).
99 Forrester (1971), Meadows et al. (1972), Meadows (1980), Moxness (1998), and Sterman (2000).
100 Richardson and Pugh (1981), Sterman (2000), and Sterman (2009).

1. Problem articulation

"Always model a problem. Never model a system"

– Sterman (2000, *page 90*).

The most important step in system dynamics modelling is problem articulation in order to have a clear purpose in developing the model because every model is a representation of a system[101]. However, for a model to be useful, it must address a specific problem and must simplify rather than attempt to replicate an entire system in detail.

The initial characterisation of the problem is developed through discussion with the experts in the field, archival research, data collection, interviews, and direct observation or participation. There are two most useful processes are establishing reference modes and explicitly setting the time horizon.

Reference modes: Literally a set of graphs and other descriptive data showing the development of the problem over time. In this study, catch and effort data of Indian mackerel, the number of vessels and fishing license are graphed to see the potential problems.

Time Horizon: The time horizon should extend far enough back in history to show how the problem emerged and describe its symptoms. It should extend far enough into the future to capture the delayed and indirect effects of potential policies. The choice of time horizon radically influences the perception of the problem. Here in this model, the time horizon is between 1980 and 2018 and the projections would be 32 years from 2018.

Knowing the problem of a system and the purpose of the model can be a reference in formulating dynamic hypothesis.

2. Formulation of dynamic hypothesis

The minute the problem of a system has been identified and characterised over an appropriate time horizon, a theory is developed and it is known as the dynamic hypothesis to account for the problematic behaviour. The hypothesis considers dynamics because it must provide an explanation of the dynamics characterising the problem in terms of the underlying feedback and stock and flow structure of the system. It is a hypothesis because it is always provisional, subject to revision or abandonment from the modelling process and from the real world[102].

From theories about the causes of the problem, the next stage is to develop an endogenous explanation for the problematic dynamics. An endogenous means "arising from within". It generates the dynamics of a system through interactions of variables and agents represented in the model.

In contrast, a theory relying on exogenous variables which means "arising from without" explains the dynamics of variables that are important in terms of other variables that is assumed.

101 Sterman (2000), and Saeed (2003).

102 Sterman (2000)

3. Formulation of a simulation model

Once an initial dynamic hypothesis has been developed (the causal loop diagrams), it is then translated into a stock and flow diagram. The stock and flow diagram can be easily developed by using system dynamics software such as Vensim, Powersim, Stella and iThink.

All the assumptions, initial conditions and equations are incorporated in the stock and flow diagram.

The stock and flow diagram demonstrates the relationship among variables which have the potential to change over time. Basically, there are four elements in the diagram as follows:

(i) Stock (level): accumulation of a system and affected by initial and rate values. Only stock can be connected by a rate or auxiliary variables.

(ii) Flow (rate): the flow will change the level with a certain rate value.

(iii) Flow of material: flow from one level to another level, which is determined by the equation of rate.

(iv) Flow of information: function of decision-making that do not directly affect the variable.

4. Testing

Testing begins once the equations in the model are completed. Part of the testing is comparing the simulated behaviour of the model to the actual behaviour of the system. However, testing encompasses far more than the replication of historical behaviour but must correspond to a meaningful concept in the real world. Every equation in the model are checked for dimensional consistency. The sensitivity of model behaviour and policy recommendations are assessed in light of the uncertainty in assumptions, both parametric and structural[103].

The model is then tested under extreme conditions which may never been observed in the real world i.e. what happens to the paddy yield, expected profitability and SSL when the subsidies are withdrawn by the government?

These extreme conditions tests, along with other tests of model behaviour, are critical tools to discover the flaws in the model and set the stage for improved understanding.

5. Policy design and evaluation

In this stage, the model is used to test various policy alternatives that might be implemented. Furthermore, researchers will be able to evaluate the impacts of the current government policies in the system being studied.

Policy design is much more than changing the values of parameters such as number of licensing or number of vessels. Policy designs includes the creation of entirely new

103 Sterman (1984), and Sterman (2000).

strategies, structures, and decision rules. Sterman (2000) applied these principles to create a dynamic model[104]:

- The state and the desired state need to be distinguished in the model;
- The structure of stock and flow in the real system should be represented in the model;
- Flows which are conceptually different, need to be distinguished;
- Only available information for the actors in the system to be used in the modelling the decisions;
- The structure of decision-making rules in the model should fit with the management practices; *and*
- The model must be robust in extreme conditions.

104 Sterman (2000)

GLOSSARY

Archetypes: Common system structures that produce characteristic patterns of behaviour.

Balancing feedback loop: A stabilizing, goal-seeking, regulating feedback loop, also known as a "negative feedback loop" because it opposes, or reverses, whatever direction of change is imposed on the system.

Causal Loop Diagram: A conceptual system dynamics tool which represents a closed loop of cause-effect linkages (causal links) as a diagram which is intended to capture how the variables interrelate. Causal loop diagrams identify and label feedback loops to facilitate dynamic reasoning and formal modelling.

Dynamic equilibrium: The condition in which the state of a stock (its level or its size) is steady and unchanging, despite inflows and outflows. This is possible only when all inflows equal all outflows.

Dynamics: The behaviour over time of a system or any of its components.

Feedback loop: The mechanism (rule or information flow or signal) that allows a change in a stock to affect a flow into or out of that same stock. A closed chain of causal connections from a stock, through a set of decisions and actions dependent on the level of the stock, and back again through a flow to change the stock.

Flow: Material or information that enters or leaves a stock over a period of time.

Hierarchy: Systems organized in such a way as to create a larger system. Subsystems within systems.

Limiting factor: A necessary system input that is the one limiting the activity of the system at a particular moment.

Linear relationship: A relationship between two elements in a system that has constant proportion between cause and effect and so can be drawn with a straight line on a graph. The effect is additive.

Non-linear relationship: A relationship between two elements in a system where the cause does not produce a proportional (straight-line) effect.

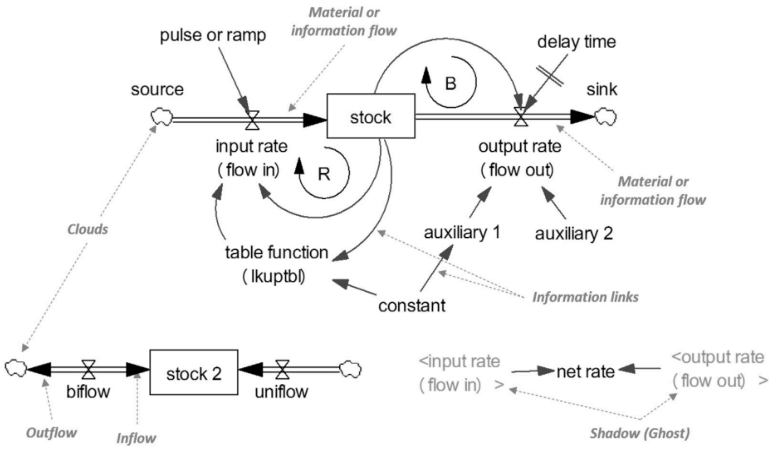
Reinforcing feedback loop: An amplifying or enhancing feedback loop, also known as a "positive feedback loop" because it reinforces the direction of change. These are vicious circle and virtuous circles.

Stock: An accumulation of material or information that has built up in a system over time.

System: A set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its "function" or "purpose."

The Tragedy of the Commons: When there is a commonly shared resource, every user benefits directly from its use, but shares the costs of its abuse with everyone else. Therefore, there is very weak feedback from the condition of the resource to the decisions of the resource users. The consequence is overuse of the resource, eroding it until it becomes unavailable to anyone.

Icons used In System Dynamics Programming:



- Stocks represent accumulations (expressed mathematically as integrals).
- Inflows and outflows change the level of the stock over the given time-step and are influenced by current system stock levels, auxiliary functions (which can take on any large number of potential mathematical functions; e.g., pulses; ramps; graphical or table; etc.), and delays, each connected through an information link.
- Clouds represent the model boundaries (i.e., sources and sinks), while shadows represent variables used in one location that have been formulated in another. The "R" symbol represents reinforcing (or positive) feedback (also denoted "+") while the "B" symbol represents balancing (or negative) feedback processes (also denoted "-").

Simulation Software

For simulation exercise, the study used the Vensim DSS (Decision Support System) software version 5.9e (Ventana Systems, Inc., Harvard, MA, USA). Other simulation softwares include iThink, STELLA, Powersim Studio, and AnyLogic.

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