

# **The IAFOR Academic Review**

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Collected  
Essays on  
Sustainable  
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## Editorial Committee Introduction

Welcome to Issue 8 Volume 1 of *The IAFOR Academic Review*. One of the central missions of The International Academic Forum (IAFOR) is to provide avenues for academics and researchers to be international, intercultural and interdisciplinary. One of the ways in which we do this is through our in-house publication *Eye Magazine*, our various conference proceedings, our journals, and now beginning in 2015, are our special editions of the *The IAFOR International Academic Review*. In this edition we, the editorial committee, bring together a selection of the most interesting contributions from our conferences with respect to the discussion of Sustainable Development and the Environment. Sustainability Development is ultimately about the interplay between people and ecologies by helping to meet the world's growing resource needs economically, culturally, socially and environmentally in the most responsible way possible. The papers selected by the editorial committee for this special edition certainly reflect the international, intercultural and interdisciplinary approach that lies at the heart of both IAFOR and the global goals of sustainable development and the environments we work and live in.

Sincerely,

**Michael Liam Kedzlie**

Editor

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**Julie Winnard** is an industrial doctorate Research Engineer at the Centre for Environmental Strategy, University of Surrey, United Kingdom, studying the integration of sustainability into engineering and business strategy. She is an experienced Chartered Mechanical Design Engineer and Project Manager, specialising previously in product innovation & design, and development activities from strategy planning onwards. Working mainly in the automotive industry with Lucas Industries, Ford and Visteon, but also in clean-tech start-up and underground rail infrastructure renewal, she has an abiding interest in the practical and effective applications of sustainability within industry and business, and has tested the results of her research in other sectors. She is also active in developing and supporting the engineering profession: recently helping to found a new professional association to develop and spread sustainability engineering knowledge and skills, the Global Association for Transition Engineering (GATE). **Andy Adcroft** is the Deputy Head of the Surrey Business School, and MBA Programme Director at University of Surrey. Professor Adcroft is currently collecting data for a year-long study into how motivations to learn and learning strategies change over time in relation to academic performance. **Jacquetta Lee** joined the Centre for Environmental Strategy at the University of Surrey in January 2003, as a Research Fellow, developing, co-ordinating and undertaking a two-year research project funded by Leverhulme Trust on "The Role of Media in Decision Making – Influencing Environmental Attitudes and Behaviours Through Soap



Operas". Prior to joining CES, Jacquetta worked at Rolls-Royce as a principle technologist in the environmental strategy team, undertaking LCA studies of key products, and developing and implementing DfE guidelines and strategy for the company. She has also worked as a site design engineer in China, as one member of a team overseeing the construction and fit out of a new five star hotel. **David Skipp** is part of the management team at the Department of Sustainability Planning, Ford Motor Company Ltd, Laindon, UK and works to assist his organisation to fully integrate sustainability issues into the core business structures and processes, rather than manage them separately, as most other commercial organisations still continue to do.

**Eileen Kae Relao** is an emerging academic who was born in Quezon City, Philippines. She graduated cum laude from University of the Philippines where she majored in BA Speech Communication, with her undergraduate thesis being recognised as one of the best theses of 2011. Eileen has been with the Department of Communications since 2012, teaching undergraduate communication courses. She has at the same time been pursuing a master's degree in International Studies through the University of the Philippines Department of Political Science.

**Peter Yang** was formerly a researcher in international economics in China who wrote on its economic reform policies and strategies. Currently, he is an associate professor at the Case Western Reserve University, USA and teaches courses on Global Studies and Sustainable Studies among other courses. His research focuses on comparative studies of major economies' government policies on sustainable development.

**Hugh Byrd** is a registered architect, in both New Zealand and the UK, who practices, teaches and researches issues of sustainability in the built environment. Since obtaining a Ph.D. in 1981 he has been involved in both academic and commercial research including work for universities, government bodies and private companies in the UK, Malaysia and New Zealand. His research encompasses the future forms of buildings and cities in response to energy depletion and climate change. He has published articles and books on environmental modelling, healthy homes, environmental rating tools, renewable energy, urban form and energy policy in both temperate and tropical countries. After teaching and researching at several universities in the UK, Hugh became Professor at the Universiti Sains Malaysia, before moving on to the School of Architecture at the University of Auckland. Recently Hugh has taken up the Professorial Chair at Lincoln University (UK).

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# Environmental Sustainability Drivers: A Study On Malaysian Palm Oil Industry

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## Abstract

Industrial practitioners and policy makers in the Malaysian palm oil industry are now focusing on understanding the factors that influence sustainability of palm oil supply chain network involving the fundamental principle of triple bottom line of social, environmental, and economic performance impacts of supply chain network design. In order to achieve sustainable products, an interpretive structural modelling approach method was used to better understand the drivers related to environmental sustainability reporting in the supply chain network related to the Malaysian palm oil industry. This paper has identified nine (9) environmental sustainability drivers and the relationships between them. The findings from the environmental sustainability reporting drivers of this study can be furthered use to explore the potential impacts of supply chain network design on sustainability using the Malaysian palm oil industry as a reference. The novelty of this research is that it identifies the significance of environmental sustainability reporting based on the analyzed drivers and provides evaluation of environmental sustainability criteria's. This paper has provided a structural model of environmental sustainability and its associated method was developed by using the interpretive structural modelling model to determine the potential drivers in environmental sustainability reporting.

## 1 Introduction

With the rapidly growing world population, the demand for palm oil is increasing. Among the 17 world major oils and fats, palm oil has made impressive and sustained growth in the global market. In 2008, palm oil accounted for 54% of the world's production of oils and fats; it is projected that palm oil will become the leading oil in the world around year 2016 [14]. Malaysia is the world's second largest producer and exporter of palm oil after Indonesia; in 2007 it produced about 15.8 million tons of palm oil. In year 2020, production is forecast to increase to 18.5 million tons. Key challenges to the palm oil industry include misconceptions on palm oil sustainability and awareness of its potential in the global vegetable oil market, consumer demands for certification of products and processes and the competitiveness on the triple bottom line performances as uncertainties to the supply network.

Sustainability of palm oil is important if this versatile crop is to become the leading vegetable oil in the world. This multipurpose vegetable oil needs to be cultivated to ensure sustainable development from the environmental, social and economic aspects. With the world's population expected to increase to 8 billion in 2028, palm oil has the potential to be the source of fats and vegetable oil to feed the people around the globe [2, 3]. As high demand of cheap and quality vegetable oil is needed to feed the world's growing population, building a tool to improve the performance of sustainability of the palm oil supply chain network involving real-time data is necessary in order to achieve sustainable production. In this context, all parties involved with palm oil like plantation owners, financial institutions and banks, manufacturers of palm oil products and governments play an active role to realise this win-win situation for all. Hence, the time has come for all parties to co-operate and realise a sustainable production and development of palm oil. Ideas and efforts will become futile if all parties do not take an active and responsible role towards this aim as sustainable development of palm oil requires collaboration and initiative among the stakeholders.

Sustainability is also particularly important when it comes to the production of food, especially commodities that are widely used by the global food industry. The need to produce palm oil sustainably has led to the establishment of the Round Table on Sustainable Palm Oil [16]. This roundtable is a platform to reach mutual understanding at the international level among various palm oil stakeholders namely; oil palm growers, palm oil processors/traders, consumer goods manufacturers, retailers, investment organizations, social or development Non-Governmental Organizations and environmental or nature conservation Non-Governmental Organizations. This understanding would be translated into common actions towards achieving sustainability of palm oil production and used in its entire supply chain. The Round Table on Sustainable Palm Oil has progressed towards formulating a set of principles and criteria for sustainable production, but has yet to implement a scheme to enable sustainably produced palm oil to be certified with full traceability. It is not easy to implement such an ambitious scheme, since maintaining the chain of custody for traceability purposes will be difficult and expensive. The importance of studying these environmental, social and economic issues, such as land conversions, productivity and environmental problems were also addressed by Sustainable Agriculture Initiative Platform and Sustainable Food Lab in Short Guide to Sustainable Agriculture documents [17, 18]. This is particularly important with the increased awareness of the environmental, social and economic issues as one of the key factors which influence consumer's perception towards sustainability in markets such as Europe.

### 1.1 Sustainability SWOT Analysis of the Malaysia Palm Oil Industry

SWOT analysis is an important support tool for decision-making, and is commonly used as a means to systematically analyse an organisation's internal and external environments [7, 10]. By identifying its strengths, weaknesses, opportunities, and threats, the organisation can build strategies upon its strengths, eliminate its weaknesses, and exploit its opportunities or use them to counter the threats. Strengths, weaknesses, opportunities and threats of the Malaysian palm oil industry in its present state from the SWOT analysis are presented in Figure 1.

The preliminary study of SWOT analysis was done to build understanding of the supply network in the Malaysia palm oil industry sector by carrying out semi-structured interviews. The objective was to review the literatures from academic and industrial viewpoints on the development of palm oil industry in Malaysia and categorise the findings into strengths, weaknesses, opportunities and threats and as well as in the form of semi-structured interviews. From the inputs of these interviews, data and information related to the palm oil industry corresponding to the research topic in Malaysia can be used for a better understanding of the supply network sustainability issues.

Strengths	Weaknesses
-The Malaysian palm oil industry is considered the second largest in the world after Indonesia.	-Poor performance of plantation segments.
-The Malaysian palm oil industry is greatly supported by its local government.	-Changes in the weather patterns worldwide can affect Malaysia's palm oil plantation and production.
-Palm oil itself is a resource that is used for the production of diverse products (part of agricultural diversifications).	
-Geographical diversifications.	
Opportunities	Threats
-The support of the country's government and agencies to the industry in research findings.	-Shortage of labour is one of the main threats of the palm oil industry in Malaysia.
-Increasing demand of biofuels derived from palm oil and biomass from plantations which can be used as alternatives to fossil fuels such as diesel. [Palm oil gives high yields at low prices and is likely to be important in biofuel demand].	-The palm oil industry in Malaysia faces other other significantly growing competition with other foreign producers.
	-The country is also experiencing lower land meeting availability for future expansion for palm oil plantation.

Figure 1: SWOT Analysis for Malaysia palm oil industry [11,12,13]

## 1.2 ISO Standards

A range of standards have been developed in the last two decades to enable sustainable development [4]. ISO 14000 standards create a systematic approach for reducing the impact on the environment due to the activities of an organization [5]. ISO 14000 standards include the ISO 14020 series for environmental labelling, ISO 14040 for Life Cycle Assessment, ISO 14064 for Green House Gases, as a few given examples. ISO 19011 provides guidelines for auditing quality and environmental management systems [6]. Figure 2 showed the examples of identified environmental sustainability drivers of life cycle stages which can be used for the proposed environmental sustainability reporting of the palm oil industry.

	Raw Material	Product Manufacturing	Transportation	Product Use	Product After Use
<b>Environmental Sustainability Drivers</b>					
1)Environmental Management	•	•	•		
2)Life Cycle Assessment	•	•	•	•	•
3)Green Labelling		•			
4)GHG Emissions		•	•		•
5)Climate Change	•				•
6)Energy Efficiency	•	•	•		
7)Renewable Resources	•				•
8)Water, Soil & Air Quality	•	•	•	•	•
9)Waste Management	•	•			•

Figure 2: Examples of identified environmental sustainability drivers of life cycle stages

### (i) Environmental Management

A number of palm oil mills and palm oil refineries in Malaysia have achieved certification to this ISO standard of environmental management. The standard requires organizations to assess their environmental impacts and develop an environmental policy to address them. The two specific requirements of relevance are:

- the policy includes a commitment to comply with relevant environmental legislation and regulations; and
- the policy includes a commitment to prevention of pollution.



Environmental management is an auditable standard that provides a framework for organizations to implement their environmental policies and can be verified by third party certification.

**(ii) Life Cycle Assessment**

In the ISO 14000 family of standards, the ISO 14040 standard provides the framework and guidance for conducting life cycle assessment (LCA). This is the “cradle-to-grave” approach for assessing the environmental profile and performance of a product from sourcing of raw materials to its final disposal after the useful life of the product. Application of this methodology to the palm oil industry would provide an assessment of the potential environmental impacts of all inputs and outputs throughout the production chain from the planting of the palm oil seed to the consumption of the final processed product.

**(iii) Green Labelling**

Green labelling refers to a scheme which awards green label to environmental friendly products. These are products that have less environmental impacts. The purpose of labelling these products is to help consumers to identify and purchase those products that are environmentally friendly. Strong demand from the consumers for environmental labelling products will encourage more manufacturers to adopt environmental friendly policies.

**(iv) Greenhouse Gas Emissions**

Carbon conservation aspects need to be addressed and greenhouse gas balance and land use competition should also be included in the design of sustainable industrial systems for the palm oil industry. Additional principles should be developed for palm oil sustainability, to cover aspects related to carbon balance and preservation of carbon stocks. As reducing greenhouse gas emissions is a prominent goal for sustainable development policies, certain levels of greenhouse gas reductions based on a life cycle assessment should be developed.

**(v) Climate Change**

Forest conversion by plantation companies contributes to climate change. Emission of carbon dioxide known as the greenhouse gas is a cause of global warming and climatic change. The rainforests which are cleared to make place for palm oil plantations are storing huge amounts of carbon. Massive amounts of carbon are released straight into the atmosphere but the land’s ability to take up carbon dioxide is also diminished with these land conversions.

**(vi) Energy Efficiency**

Increasing energy efficiency will help to reduce the impact of energy consumption on climate change by replacing non-renewable energy with alternative renewable and low impact energy sources.

**(vii) Renewable Resources**

The efficient use of renewable resources should be targeted since the use of non-renewable resources, such as fossil fuel, is not sustainable in the long term. Greenhouse gases and polluting gaseous emissions must be minimised.

**(viii) Water, Soil and Air Quality**

During planting, several measures must be taken to prevent soil degradation and conserve soil fertility in order to minimise soil erosion and fertilizer loss. The soil is highly susceptible to erosion during the land preparation stage preceding planting palm oil trees are unique in a way that they have higher leaf area index that allows them to have better photosynthetic efficiency to produce more oxygen to the air and absorb more carbon dioxide from the atmosphere. Water quality around palm oil plantations and processing mills must be carefully handled to avoid from the impacts of using banned herbicides and pesticides for the use to control weeds and pests. Oily sludge of palm oil mill effluent from palm oil processing mills must be treated before being discharged into water systems to avoid water supply contamination.

**(ix) Waste Management**

All waste must be handled, stored and disposed off correctly to avoid pollution to minimize the amount of waste produced, thus reducing environmental cost and ensuring that legislative requirements are met.

## **2 Materials and Methods**

Interpretive structural modelling was first proposed by Warfield [22]. Interpretive structural modelling referred henceforth as ISM, is aid for modelling relational structure among the number of parameters. While dealing with large number of attributes, it gets complicated to relate them with reference to the final goal. Interpretive structural modelling can help in interpreting the decision maker’s judgment about relation among the parameters. It extracts a structured model out of pool of parameters to simplify decision making process.

The major steps involved in using interpretive structural modelling are as follows:

- (i) Identification of parameters  
The relevant parameters to be considered in final analysis are listed in Figure 2.
- (ii) Structural self interaction matrix  
Depending on the situation and parameters, a contextual relation is chosen and compared with every other parameter to decide presence and direction of chosen relationship. This generates self interaction matrix.
- (iii) Reachability matrix  
From the self interaction matrix, the relational indicators are converted in to binary digits 0 and 1 to get a square matrix, called reachability matrix. Simple transitivity check is done as, if parameter A relates to B and B relates C then A relates to C. This helps in extracting a consistent model from the set of parameters. Summations of row indicate driving power of the parameters and summations of column indicate dependence. Higher dependence rank and lower driver rank indicates dependent parameters, whereas lower dependence rank and higher driver rank indicate independent parameters. Lower dependence and driver rank indicate autonomous parameter, whereas higher dependence and driver rank indicate linked parameters.
- (iv) Level partition  
From reachability matrix, for each parameter, reachability set and antecedent sets are derived. Reachability set contains parameter itself and other parameters to which it may reach. Antecedent set contains parameter itself and other parameters, which may reach to it. Depending on intersection of these sets, the parameters are partitioned in hierarchical levels.
- (v) Construction of interpretive structural modelling  
From the partitioned set of parameters and reachability matrix, structured model is derived, indicating parameters in each level and arrows indicating direction of relationship present. Such a graphic representation of model is called diagraph.

The various steps involved in interpretive structural modelling methodology are shown in the flowchart in Figure 3 modified from Kannan et. al [8].

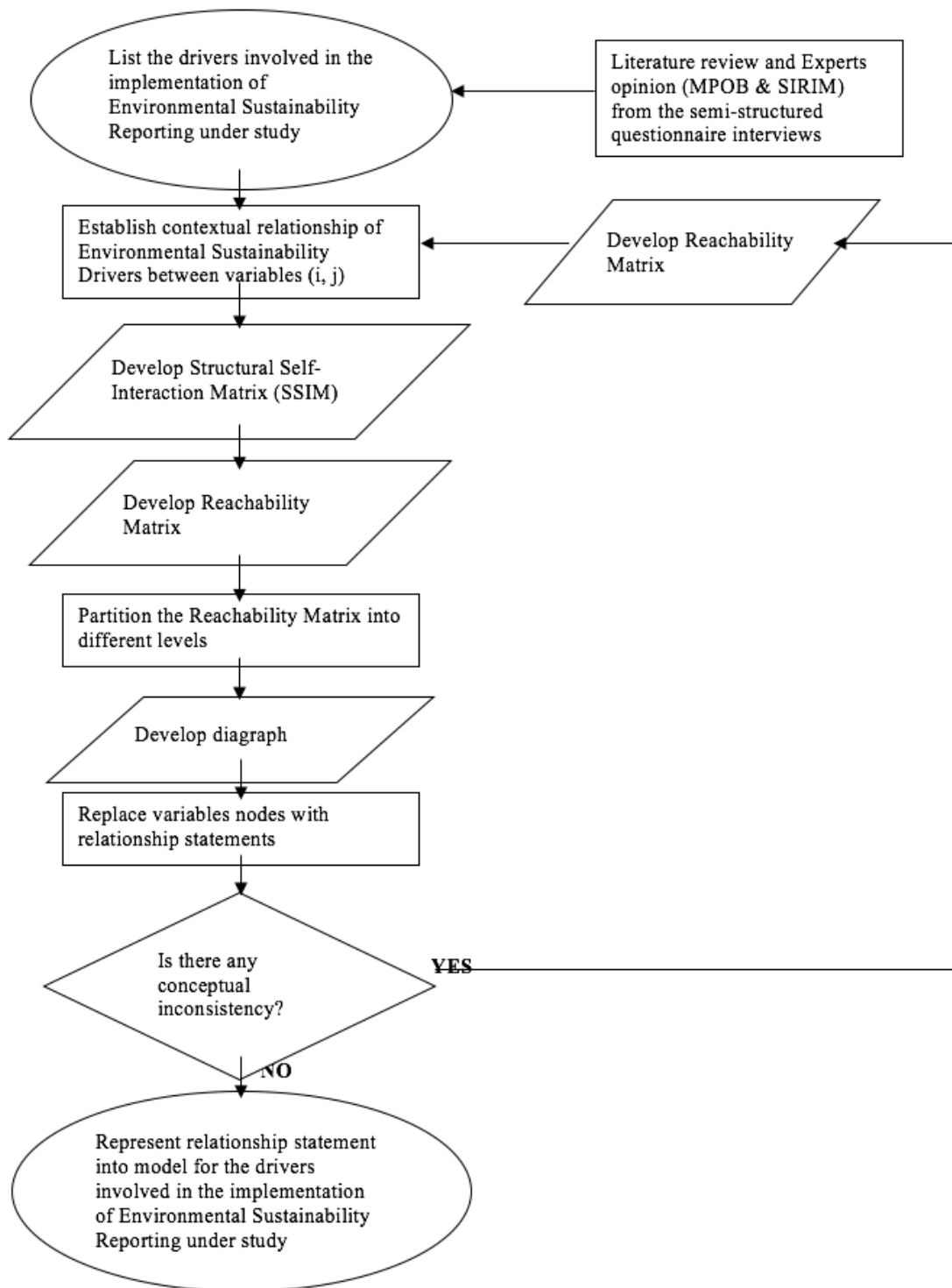


Figure 3: Flowchart of interpretive structural modelling methodology



### 3 Results and Discussion

#### 3.1 Structural self-interaction matrix

The first step is to analyze the contextual relationship of type “leads to”. That is one Environmental Sustainability leads to another. Based on this contextual relationship, a structural self-interaction matrix is developed. In this research, 3 experts, from the research based industries were consulted in identifying the nature of contextual relationship among the environmental sustainability drivers.

Following, four symbols are used to denote the direction of relationship between the Environmental Sustainability Drivers (I and J):

- V: Environmental Sustainability Drivers of I will help to achieve Environmental Sustainability Drivers of J

Environmental Sustainability Drivers of I	Will help to achieve	Environmental Sustainability Drivers of J
Water, Soil and Air Quality		Climate Change
Renewable Resources		Green Labelling Life Cycle Assessment
Energy Efficiency		GHG Emissions Life Cycle Assessment Environmental Management

Water, soil and air quality (without pollution) determine agricultural sustainability [1, 19] and environmental quality [20] and have impacts on environmental pollution, degradation and depletion of natural and non-renewable resources [21]. Applying renewable resources will minimise pollution and by using green labelling and life cycle assessment will help to provide qualitative and quantitative information regarding consumption of material. Energy use is a major source of emissions, thus achieving energy efficiency is important to control greenhouse gas emissions, assessing life cycle and managing the environment.

- A: Environmental Sustainability Drivers of J will be achieved by Environmental Sustainability Drivers of I

Environmental Sustainability Drivers of J	Will be achieved	Environmental Sustainability Drivers of I
Renewable Resources		Climate Change
Climate Change		Life Cycle Assessment Environmental Management
Green Labelling		Environmental Management

Concerns about degradation of natural resources and climate change have triggered the need for preventive measures of environmental protection. Promotion of renewable resources and green labelling will be achieved by implementing life cycle assessment and environmental management systems. These will help to reduce the greenhouse effect.

- X: Environmental Sustainability Drivers of I and J will help to achieve each other

Environmental Sustainability Drivers of I	Will help to achieve each other	Environmental Sustainability Drivers of J
Waste Management		Water, Soil and Air Quality Renewable Resources Energy Efficiency Green Labelling Life Cycle Assessment Environmental Management

Water, Soil and Air Quality		Renewable Resources GHG Emissions Life Cycle Assessment Environmental Management
Renewable Resources		Energy Efficiency Environmental Management
Energy Efficiency		Climate Change
Climate Change		GHG Emissions
GHG Emissions		Green Labeling Life Cycle Assessment Environmental Management
Green Labelling		Life Cycle Assessment
Life Cycle Assessment		Environmental Management

The development of an Environmental Management System (EMS) includes rational land use planning, water management, energy management (promotion of renewable energy sources, promotion of clean and energy efficient technologies), waste management (minimization, recovery, reuse, recycle, etc.) and life cycle assessment.

- O: Environmental Sustainability Drivers of I and J are unrelated

Environmental Sustainability Drivers of I	Unrelated to	Environmental Sustainability Drivers of J
Waste Management		Climate Change GHG Emissions
Water, Soil and Air Quality		Energy Efficiency Green Labelling
Renewable Resources		GHG Emissions
Energy Efficiency		Green Labelling
Climate Change		Green Labelling

Waste management is regarded to re-use, recycle, repair, life extension, incineration (with or without energy recovery), landfill and composting and is unrelated to climate change and GHG emissions. Water, soil and air quality are referred to unpolluted and emissions which can lead to erosion, climate change and ozone depletion. They are not related to energy efficiency and green labelling. Renewable resources are non-depletable resources which can be used in a cleaner and more efficient technologies manner and non-related to GHG emissions. Energy efficiency and climate change are not related to green labelling.

Based on expert's responses, the structural self-interaction matrix is constructed as shown in Table 1.

Table 1: Structural self-interaction matrix for Environmental Sustainability

Environmental Sustainability	9	8	7	6	5	4	3	2	1
1.Environmental Management	X	X	X	V	A	X	A	X	-
2.Life Cycle Assessment	X	X	V	V	A	X	X	-	
3.Green Labeling	X	O	V	O	O	X	-		
4.GHG Emissions	O	X	O	V	X	-			
5.Climate Change	O	V	A	X	-				
6.Energy Efficiency	X	O	X	-					
7.Renewable Resources	X	X	-						
8.Water, Soil and Air Quality	X	-							
9.Waste Management	-								

### 3.2 Reachability matrix

The structural self-interaction matrix for environmental sustainability is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1s and 0s are as follows:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Then its transitivity is checked (which means if Environmental Sustainability of i leads to Environmental Sustainability of j and Environmental Sustainability of j leads to Environmental Sustainability of i, then Environmental Sustainability of i should lead to Environmental Sustainability of j) and the final reachability matrix as shown in Table 2 is obtained. In this table, the driving power and dependence of each Environmental Sustainability's are also shown. The driving power of a particular Environmental Sustainability is the total number of Environmental Sustainability (including itself) which it may help to achieve. The dependence is the total number of Environmental Sustainability which may help achieving it.

Table 2: Final reachability matrix

Environmental Sustainability Drivers	1	2	3	4	5	6	7	8	9	Driving Power
1.Environmental Management	1	1	0	1	0	1	1	1	1	7
2.Life Cycle Assessment	1	1	1	1	0	1	1	1	1	8
3.Green Labelling	1	1	1	1	0	0	1	0	1	6
4.GHG Emissions	1	1	1	1	1	1	0	1	0	7
5.Climate Change	1	1	0	1	1	1	0	1	0	6
6.Energy Efficiency	0	0	0	0	1	1	1	0	1	4
7.Renewable Resources	1	0	0	0	1	1	1	1	1	6
8.Water, Soil and Air Quality	1	1	0	1	0	0	1	1	1	6
9.Waste Management	1	1	1	0	0	1	1	1	1	7
Dependence Power	8	7	4	6	4	7	7	7	7	

### 3.3 Level partitions

From the final reachability matrix, the reachability set and antecedent set for each ES is found. The reachability set includes Environmental Sustainability itself and others, which it may help to achieve similarly the antecedent set consists of Environmental Sustainability itself and the other Environmental Sustainability's which help in achieving it. Then, the intersection of these sets is derived for all Environmental Sustainability's. The Environmental Sustainability for which the reachability and intersection sets are same is the top-level Environmental Sustainability in the interpretive structural modelling hierarchy.

Table 3: Iteration i

Environmental Sustainability Drivers	Reachability Set	Antecedent Set	Intersection Set	Level
1.Environmental Management	1,2,4,6,7,8,9	1,2,3,4,5,7,8,9	1,2,4,7,8,9	I
2.Life Cycle Assessment	1,2,3,4,6,7,8,9	1,2,3,4,5,8,9	1,2,3,4,8,9	
3.Green Labeling	1,2,3,4,7,9	2,3,4,9	2,3,4,9	
4.GHG Emissions	1,2,3,4,5,6,8	1,2,3,4,5,8	2,3,4,5,8	
5.Climate Change	1,2,4,5,6,8	4,5,6,7	4,5,6	
6.Energy Efficiency	5,6,7,9	1,2,4,5,6,7,9	5,6,7,9	
7.Renewable Resources	5,6,7,8,9	1,2,3,6,7,8,9	6,7,8,9	



8. Water, Soil and Air Quality	1,2,4,7,8,9	1,2,4,5,7,8,9	1,2,4,7,8,9	I
9. Waste Management	1,2,3,6,7,8,9	1,2,3,6,7,8,9	1,2,3,6,7,8,9	

The top-level Environmental Sustainability in the hierarchy would not help achieve any other Environmental Sustainability above its own level. Once the top-level ES is identified, it is separated out from the other Environmental Sustainability's (Table 3). Then, the same process is repeated to find out the Environmental Sustainability's in the next level. This process is continued until the Environmental Sustainability of each level is found. Results for the iteration process are summarized in Table 4. The resulting levels help in building the digraph and the final model.

Table 4: Iteration ii-v

Iteration	ES's	Reachability Set	Antecedent Set	Intersection Set	Level
ii	2	2,3,4,6,7,9	2,3,4,5,9	2,3,4,9	II
ii	3	2,3,4,7,9	2,3,4,9	2,3,4,9	II
iii	7	5,6,7,9	6,7,9	6,7,9	III
iii	9	6,7,9	6,7,9	6,7,9	III
iv	4	4,5,6	4,5	4,5	IV
iv	5	4,5,6	4,5,6	4,5	IV
v	6	6	6	6	V

### 3.4 Building the ISM model

From the final reachability matrix (Table 2), the structural model is generated. If there is a relationship between the Environmental Sustainability's I and J, this is shown by an arrow which points from I to J. This graph is called a directed graph, or digraph. After removing the transivities the digraph is finally converted into the interpretive structural modelling-based model (Figure 4).

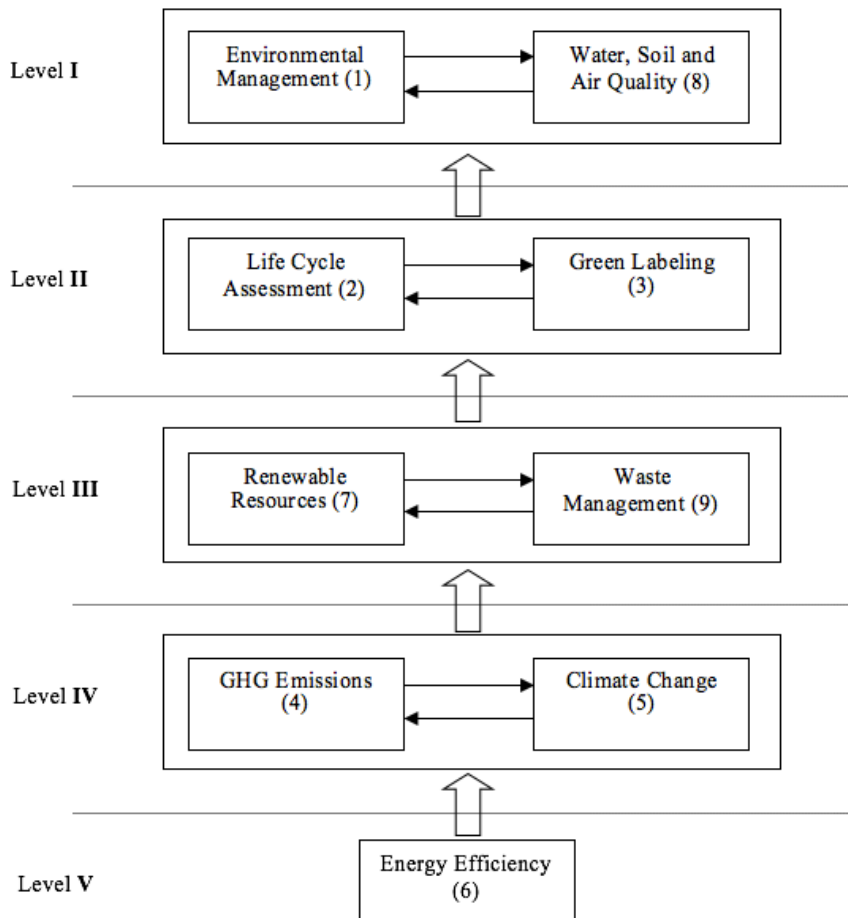


Figure 4: Structural model of Environmental Sustainability Drivers

Several interesting findings for the implementation of environmental sustainability arise from the application of interpretive structural modelling approach. The findings offered new considerations regarding the successful implementation of sustainability reporting. In this analysis, the dependence power and driver power of the variables are analyzed. On the basis of the above study, the drivers were classified into four sectors. The four sectors are autonomous, dependent, linkage, and driver/independent (refer to Figure 5). In the final reachability matrix, shown in Table 3, the driving power and dependence of each of the drivers are calculated. The drivers that have weak driver power and weak dependence will fall in Sector I and are called autonomous drivers. Drivers that have weak driver power, but strong dependence power will fall in Sector II and are called dependent drivers. Drivers that have both strong driver power and dependence power will fall in Sector III and are called linkage drivers. These drivers are unstable due to the fact that any action on these drivers will affect the others, and may also have a feedback effects on themselves. Drivers that have strong driver power but weak dependence power will fall in Sector IV and are called independent drivers [9].

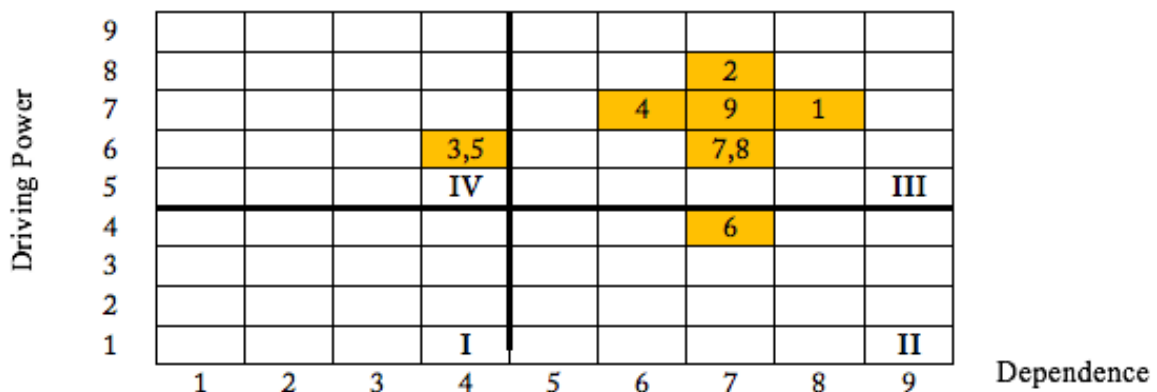
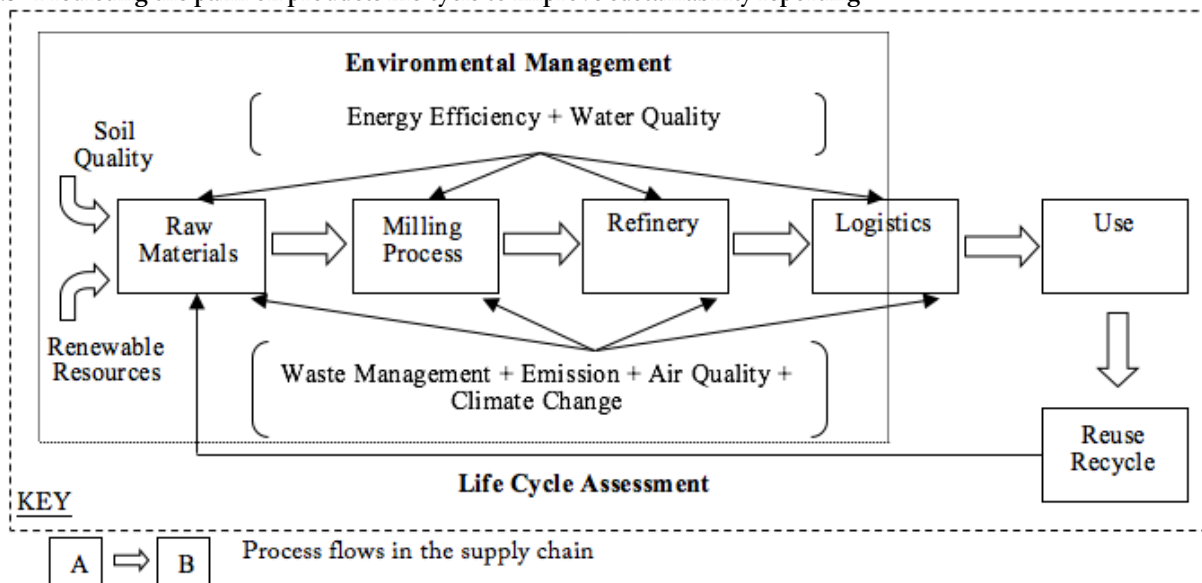


Figure 5: Driving power and dependence diagram

- Sector I: Autonomous Driver
- Sector II: Dependent Driver
- Sector III: Linkage Driver
- Sector IV: Independent Driver

### 3.5 Predicting the palm oil products life cycle to improve sustainability reporting



Process flows in the supply chain

Figure 6: Environmental sustainability reporting drivers in the Malaysian palm oil industry

The drivers involved in the environmental sustainability reporting for Malaysian palm oil industry case study pose considerable challenges. Decision makers must be aware of the relative importance of the various drivers and the techniques for implementing them. Highlighting the 9 types of drivers, an interpretive structural modelling-based model was developed and the interactions between these drivers were analyzed. From Figure 4, it is evident that energy efficiency is the significant driver to reduce and eliminate product environmental impact, which is in turn critical to achieving the sustainability certification between suppliers in the supply chain network. Life cycle assessment, green labelling, renewable resources, waste management, GHG emissions and climate change are placed at an intermediate level of the interpretive structural modelling-based model. Environmental management and water, soil and air quality are at the top level of the interpretive structural modelling-based model hierarchy.

From the driving power and dependence diagram shown in Figure 5, it is evident that there is no driver that has weak dependence and weak driving power, so there are no drivers that map to Sector I. Next, the energy efficiency driver is found to have weak driving power and strong dependence power so it maps to Sector II. In this case, implementation of environmental management, life cycle analysis, GHG emissions, renewable resources, water, soil and air quality and waste management are found to have strong driving power and strong dependence power so they map to Sector III. These drivers are unstable due to the fact that any change occurring to them will affect other drivers and may be affected through a feedback mechanism [15]. Lastly, the green labelling and climate change drivers possess strong driving power and weak dependence power so they map to Sector IV. The above model is based on the interpretive structural modelling methodology, which has its own limitations. For example there will be subjective bias of the person who is judging the drivers, as the relations among the drivers always depends on that person's knowledge and familiarity with the industry.

Issues of product sustainability are being undertaken in supply chain network by using simulation analysis and subsequently to ascertain a novel approach to outline a guideline of their product life cycle. It is intended that the standard of environmental sustainability reporting can utilize these drivers (shown in Figure 6) as part of a useful guideline to aid decision-making. The novelty of this research is that it identifies the significance of environmental sustainability reporting based on the analyzed drivers and provides evaluation of environmental sustainability criteria's. This paper has provided a structural model of environmental sustainability and its associated method was developed by using the interpretive structural modelling model to determine the potential drivers in environmental sustainability reporting. The developed model can be used in the design life cycle of a product whether it is viable to be reused, remanufactured or recycled and subsequently to improve its sustainability. Indicators and units examples of the environmental sustainability indicators and units of life cycle stages related to the Malaysian palm oil industry were shown in Table 5.

Table 5: Examples of environmental sustainability drivers' indicators and units of life cycle stages of the Malaysian palm oil industry

Environmental Sustainability Drivers	Indicators	Units
1) Environmental Management	Compliance to the Environmental Management Standards	Number or %
2) Life Cycle Assessment	A specific entire product life cycle from the environmental point of view	Number or %
3) Green Labelling	Labels on products indicating carbon footprints, water and energy use, resource consumption and health impacts	Number or %
4) GHG Emissions	Emissions in total	CO <sub>2</sub>
5) Climate Change	Contribution to global warming	equivalent kg/yr or t/yr CO <sub>2</sub>
6) Energy Efficiency	Energy used in total	equivalent TJ/yr
7) Renewable Resources	Rate of renewable resources (relative to total world/regional reserves)	%
8) Water, Soil and Air Quality		
For water	Amount of water used	m <sup>3</sup> /yr
For soil	Amount of soil used	ha/yr
For air	Amount of air pollutions	kg/yr or t/yr
9) Waste Management	Amount of solid waste (hazardous or non-hazardous)	kg/yr or t/yr

## 4 Conclusion

In order to achieve sustainable products, an interpretive structural modelling approach was conducted to better understand the drivers related to environmental sustainability reporting in the supply network chain related to the Malaysian palm oil industry. This paper has identified nine (9) environmental sustainability drivers and the relationships between them. The findings from the environmental sustainability reporting drivers of this study can be furthered use to explore the potential impacts of supply chain network design on sustainability using the Malaysian palm oil industry as a reference.

The decision makers related to the Malaysian palm oil industry will be directly benefited from the outcome of this research, as this would help them in prioritizing decision-making efforts on various issues. The strongest driver in the decision-making process of this industry is energy efficiency. By increasing energy efficiency will help to reduce the impact of energy consumption on climate change. This is perhaps the reason why issue relating to energy efficiency is in the level of the strongest driver. This issue has triggered the next level of issues, which includes greenhouse gas emissions and climate change. As climate change is primarily affected by the greenhouse gas emissions, replacing non-renewable energy with alternative renewable and low impact energy sources can help to increase energy efficiency. The next level of issues as shown in the interpretive structural modelling-based model in Figure 4 covers the issues related to renewable resources and waste management. This level of issues is primarily at the cradle-to-grave life cycle, where efficient use of renewable resources and successful implementation of waste management will ensure long term sustainability achievement. In the next level of issues, life cycle assessment and green labelling are applicable to provide an assessment of the potential environmental impacts of all inputs and outputs throughout the production chain and to produce environmental friendly products. The final issues are the environmental management and water, soil and air quality which are important to access environmental impacts and to prevent contamination.

As for further research, simulation analysis can be carried out to determine the influence effect of these drivers had on the performance of the network. From the performance analysis, focus can be better made on the sensitivity of triple bottom line to factors of uncertainties of the supply chain network in order to understand the potential risks of sustainability in palm oil supply chain network and could be diagnosed for better sustainability development indicators.

### Acknowledgment

A semi-structured questionnaire was designed to collect information related to the palm oil industry corresponding to the research topics in Malaysia. The authors wish to thank three interviewed respondents, (1) Mr. Ramli Abdullah, Senior Research Officer and (2) Ms. Dayang Nazrima Shahari, Head of Estate Section, from the Malaysia Palm Oil Board and (3) Mdm. Hasnah Mohd Zin, Environmental Technology Research Centre for their valuable information's.

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# Finding Balanced Synergies – Putting Resilient Sustainability into Business and Technical Strategy



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## Abstract

Whilst some pioneer businesses have integrated sustainability into their fundamental strategic decisions this can be a difficult task. Our recent review indicates a blend of both sustainability and resilience is needed, to ensure the reliable synergy of reduced impacts and improved performance which make up sustainable business. This is supported by recent evidence that organisations which do implement such Resilient Sustainability flourish compared to their peers, by benefiting from better risk awareness and avoidance, reduced costs, maintained access to investment, flexible solutions and improved ability to exploit opportunities. However, not much detailed help is available for less well-resourced firms on how to implement such an integration and access those benefits.

The paper reports on the development and testing of a new generic flexible approach to decision-support which aims to integrate sustainability and resilience into strategic processes. It is based on techniques from complex systems engineering and influenced by best business practice such as Porter and Kramer's Creating Shared Value. This allows decision-makers and their teams to approach

commercial and technology strategy formation in a new structured way, to identify gaps in their knowledge and create more resilient options which better balance people, planet and profit.

The research uses case studies to test the approach, within Ford Motor Company and other organisational strategy contexts. The paper summarises the findings to date, including user feedback and evidence for how the approach can deliver increased capability for managing risks and uncertainties and thus improve an organisation's strategic performance.

## 1.0 Introduction

Sustainability is increasingly a strategic issue for companies (Haanaes et al., 2012) and those which are more sustainable perform better than competitors (Eccles et al., 2012). They also need resilient strategies to maintain this performance in turbulent business conditions (Hamel and Välikangas, 2003, Bhamra et al., 2011, Taleb, 2008). Blending both qualities when making decisions is difficult yet guidance for how to do this- or even half of the task- has been almost non-existent (Bocken et al., 2013, Winnard et al., 2014). Even where executives acknowledge the strategic importance of sustainability issues for their organisations, many are not yet addressing these (Kiron et al., 2013).

Companies also cannot afford to develop every feasible single technology, business model or product option and must choose between alternatives, often at an early stage of their strategy. Therefore a new approach is needed to make the integration of sustainability and resilience into these choices more consistent and easier (Winnard et al., 2014).

### 1.1 Developing the new decision-support process

The first step was to define sustainability and resilience. It is possible to define sustainability for businesses, based on reducing their negative and improving their positive social, environmental and economic impacts and prioritising those actions which restore various forms of capital (*ibid.*). Definitions for strategic business resilience vary; possibly because it appears to consist of three main elements. Combining these gives a definition covering the capacity to continue functioning when suffering a disruption of some kind; further capacity to recover from disruption, and *adaptive capacity* for developing new abilities and resources, preferably in anticipation of problems (*ibid.*). The synergy between resilience and sustainability is not much explored but is best expressed by Walker *et al.* (2002) who suggests resilience should be developed in order to deliver sustainability reliably.

### 1.2 How this new approach benefits companies

The new blended approach was named SuReSDS™ (for Sustainable Resilient Strategic Decision-Support). In every-day business terms its purpose is to facilitate companies in managing forms of strategic and other risk better, which arise as a result of unknowns. This can be shown in the form of a "Rumsfeld" grid as in Figure 1 describing different kinds of uncertainty and risk, named for Rumsfeld's famous speech (Pullum, 2003, Steyn, 2003).

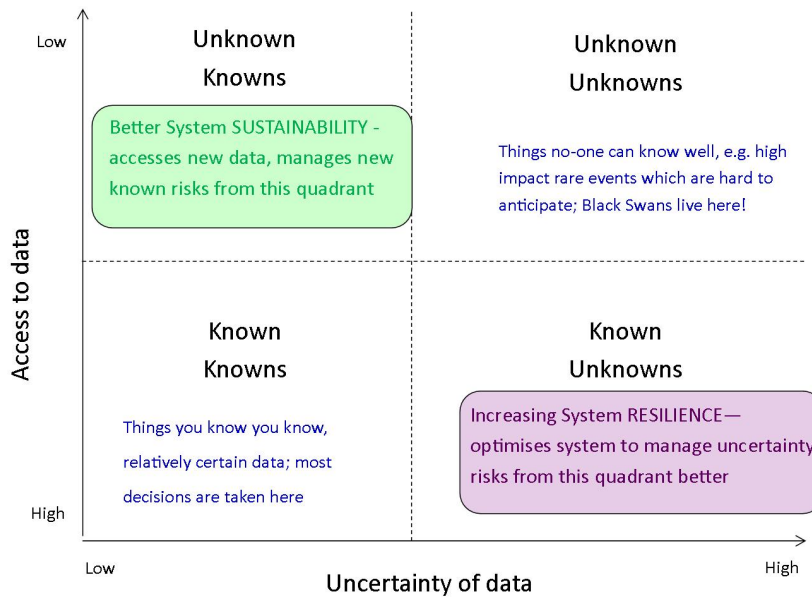


Fig. 1- Effects of SuReSDS™ on risk from unknowns

“Unknown Knowns” represents data which may be available to other organisations but not your own, for example if you are not using sustainability expertise to inform corporate strategy. “Known Unknowns” indicates chaotic random elements of the business context about which there is some information, but low certainty; for example the size and timing of commodity price fluctuations. By expanding the organisation’s capability to manage these two areas, its resilience to disruptions is improved; its sustainability risks are reduced, opportunities exploited better, and surprises have less of an impact on business performance. Although little or no data exists about events in the “Unknown Unknowns” area, the capability to handle these is also improved. The organisation becomes more capable in the other areas; therefore it becomes more resilient to the effects of some types of uncertainty and risk which also occur in this fourth category whether or not they can be anticipated.

### 1.3 SuReSDS process flow

Developed during research hosted by a manufacturing company (Ford Motor Company Ltd), the approach blends the sustainable business ethos of Creating Shared Value (Porter and Kramer, 2011) with strategy creation and comparison techniques from Transition Engineering (Krumdieck, 2013). In addition system–functionality techniques adopted from Robustness Design engineering (FMC, 2011) look rigorously at how each choice improves both sustainability and resilience. The ultimate aim is to identify the most appropriate strategy option(s) for users to adopt across a range of possible future conditions, by considering a broad range of sustainability performance criteria, alongside effects of the strategies on resilience related to risks and opportunities. The main stages are shown in Figure 2.

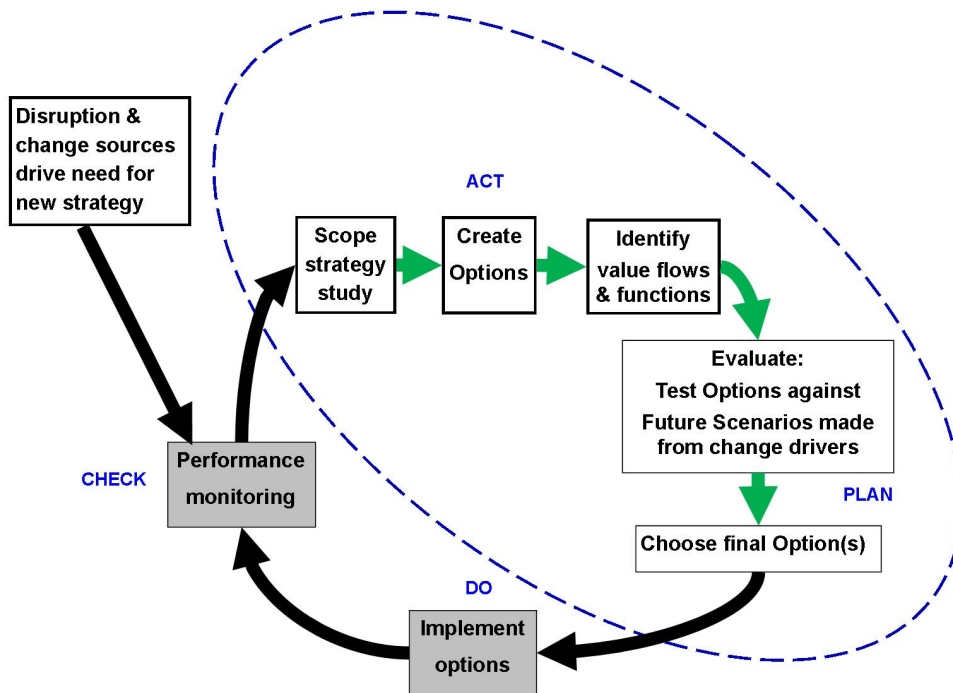


Fig. 2– SuReSDS™ process (inside dotted line) inserted into a typical Deming-style strategic decision-cycle (adapted from Arveson, 1998)

The process flow for the new approach was developed using a pilot case study, into a more detailed set of steps which could be communicated to company staff. These are shown in overview in Figure 3. The intervention point for this project, at which the new process could effectively be inserted within company activities, was identified using semi-structured interviews and meeting observations. This point was the use of strategic studies, in which teams of engineers, specialists and managers prepare information and recommendations for decision-makers at higher levels. This information is used in iterative, multi-level and multi-function decision-making loops to alter or create strategies at Ford, which may concern technologies, products and services or even business models.

## 2.0 Testing the new process

Next a process instruction manual and some simple training examples were created. Further case studies inside Ford were used to test its validity in real situations and to investigate whether it could provide the desired beneficial effects for its users. As many of Ford's strategic decisions are on future products which are commercially sensitive, and this limits the ability to publish the research results, further organisations were approached for case studies. These consisted of a nearby (non-automotive) Small to Medium-sized Enterprise (SME) manufacturer, and a non-educational department of the University.

Managers and their teams were chosen for participation in the research who said their teams already encountered issues associated with environmental or social impacts of their organisation's activity or products, and who therefore had an interest in integrating these issues within their work. Interviews recorded their existing approaches to strategic studies and strategic decision-making, before training the teams in the new process using a facilitated workshop.



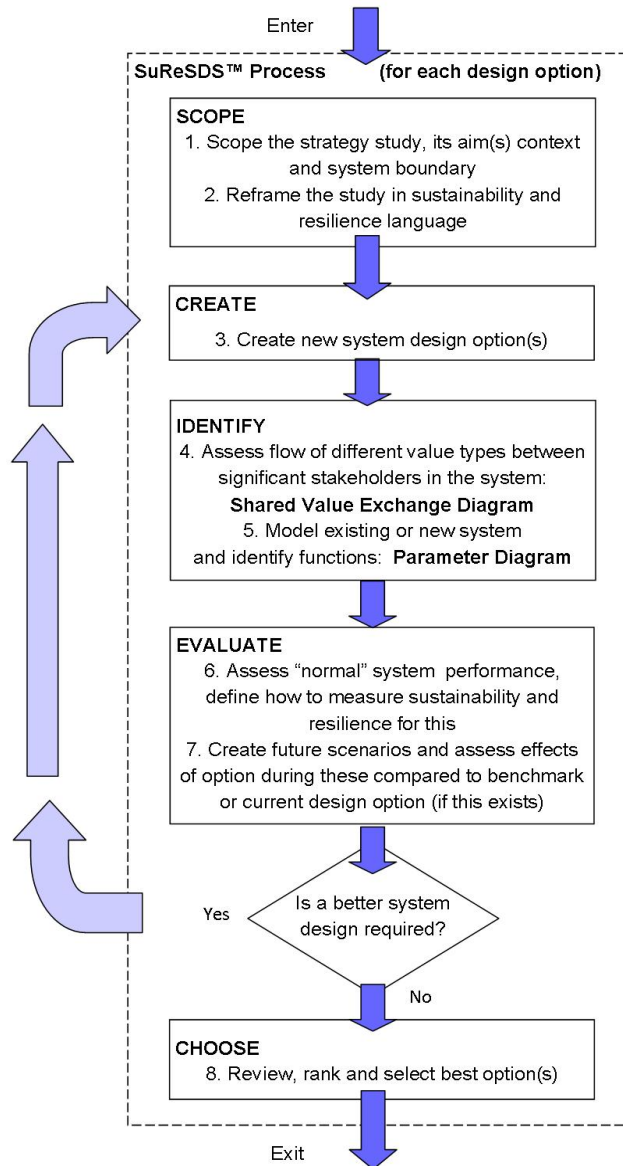


Fig. 3– The 8 steps of the SuReSDS™ process flow

The teams then applied the SuReSDS™ approach to a real-world strategic study they were working on, facilitated and observed by the researcher. After either a complete pass of the process steps, or as many as could be accommodated in the available time, feedback was sought using a short questionnaire and further interviews.

### 3.0 Case study results

The case study samples which have been completed and analysed so far have ranged from early product-service concepts, through business plans and technology roadmaps, to capital-asset planning strategy processes. The original pilot case study at Ford provided confirmation that the approach was logically valid within quantitative studies, by reproducing results from a previous study, before exploring which extra insights might be gained from using SuReSDS™. As a result of the aforementioned confidentiality concerns, this paper illustrates the results primarily using an early case sample where SuReSDS™ was used at the SME.

### 3.1 Butyl Products Ltd case study

Butyl Products Ltd is a medium-sized UK manufacturer serving several sectors. Amongst these they make aid and development equipment for charities, governments and other organisations, focussing on kits for water-related needs such as sanitation and hygiene. The study concerned the business case for, and design of, a new product, which the company wished to offer in response to an unmet hygiene need for end-users identified by customers at a recent sector workshop. This case sample was also a pilot study in that this was the first time the approach was utilised by ordinary business people outside the research project.

There were two elements to the case study design:

- Checking that SuReSDS™ would reproduce similar results during its process, to an original qualitative analysis; to show whether as an analysis approach it is logically valid.
- Testing whether SuReSDS™ produced extra information and insights. This investigated whether it enabled users to integrate resilient sustainability into their strategic choices as intended, and whether it produced extra benefits to justify the effort required to use it.

#### 3.1.1 Methodology for applying SuReSDS™

The new approach was applied to existing strategic information from a current product and business-model study, by the researcher and a specialist from the SME together. An initial analysis was produced, and the results compared to the existing study. The analysis was then extended using SuReSDS™ to look at product function, sustainability, and resilience to issues in the field. This analysis was conceptual (for a new product-service idea) and therefore qualitative rather than quantitative. The specialist was interviewed afterwards to see how useful the experience of using SuReSDS™ had been. They were asked whether it had made the decision process easier and whether it had influenced the choice of strategy, or improved business performance.

#### 3.1.2 Scope phase

The case is explained here in terms of the process steps of the new approach. The first phase is intended to clearly define the purpose of the strategic study, and to set the boundaries of the business model, product or service, or technology to which it is being applied (that is, the *system* which the strategic decision is seeking to change). It seeks to reframe the study in terms of sustainability and/or resilience issues or opportunities, to check that use of SuReSDS™ is appropriate and necessary.

The design problem to which the process was applied at Butyl Products Ltd relates to menstrual hygiene in aid camps and development projects all over the world. Butyl's clients had identified a "wicked problem" in that young women in developing nations can experience problems managing their menses discreetly, frequently staying away from school and other public activities for up to a third of each month. This means they fall behind and often drop out of general education and development projects. This matters because it undermines the social and economic development these projects are meant to support; both generally and for individual females.

Hygiene kits for aid and development treat menstrual hygiene as less important than survival and tend to contain either nothing, simple cloths, or at best Western-style adhesive disposable paper pads. These lead to several issues:

- A complete absence of menstrual hygiene supplies does nothing to alleviate the related issues for women and girls receiving kits.
- Cloths are washable so re-useable and cheap but do not work very well as they are not secure and do not stop leaks. Kits may also lack instructions and cloths may not be laundered or can end up being used for other things.

- Stick-on disposable pads attach to underwear during use and function well; except for cultures which do not wear underpants. Here even if underwear is also supplied, this and the pads are rarely used.
- Even where they are used, the disposable pads create hygiene and waste problems when disposed of after use, and users must be resupplied with new pads at further cost and logistical difficulty. When the camp closes or development project finishes, there may not be a further supply of items and project benefits may be lost.
- Finally there is a common set of issues; lack of hygiene education and lack of suitable materials, or unhygienic use arising from any of these kit options means women and girls using various unsuitable materials and methods to manage their menses. The resulting poor hygiene is thought by Non-Governmental Organisations (NGOs) to account for a significant proportion of female infections and diseases in some countries.

The company's clients at the sector workshop identified from this that they needed:

- A new design of menstrual hygiene kit which works in all cultures but also functions well generally
- To be combined with hygiene education
- And which is also low-cost enough to be used everywhere, to avoid complexity and related costs in NGO distribution and supply chains.

The NGOs and other sector organisations would supply the education side but needed their suppliers to come up with solutions for the physical items. From this Butyl had identified a potential solution but wanted to check if their intuition that it was the best suitable design solution was correct. They also needed to investigate the business case to see if the required investment in prototypes and business development was justified.

Working with the relevant specialist at Butyl, the case study was identified as seeking to primarily solve a cultural resilience design issue. This was that the best available solution for menstrual hygiene kits, stick-on pads, does not work in some cultures and so this undermines the function of the kit and other aid or development project effectiveness. The design is of a Product-Service System (PSS) in that the pads are providing the service of discreet menstrual hygiene management. This service can be thought of as the "function" of the PSS, which currently has social (cultural and also various hygiene) issues. The wish of the client NGOs was that these issues should be solved whilst improving (or at least not worsening) the environmental (mainly disposal) and economic (user purchase and/or donor cost) impacts of the system. Therefore the study was confirmed as containing both resilience and sustainability concerns, and so being suitable for applying SuReSDS™.

### 3.1.3 Create Options phase

If the organisation does not already have strategy or system design options in mind, at this stage some initial options should be created using the simple results from the scope phase. To assess any such option it is necessary to find something to compare it with; either the existing situation without the new design/strategy if it is new, or some existing variant if it is an improvement. The results of other phases of the analysis process can also trigger ideas for more changes leading to further improved function or reduced negative impacts, creating new versions of existing options. In this way SuReSDS™ has been designed from the start as an iterative process.

In this case study the company had identified a solution using a combination of design elements from existing products. They had one design concept which they could supply to customers, and so in order to analyse its benefits it was decided to compare it with the best available external option. The new design was a washable re-useable set of fabric pads combined with an elastic belt, storage bags and laundry soap. The pads were absorbent but shaped and had a waterproof layer (taking the best elements of the paper pads to provide a good basic functionality), and the elastic belt had loops and clips to secure the pads without underwear (borrowing from another older type of paper pad). The use of tough, stain-proof but soft and absorbent fabrics plus storage bags and soap allowed clean and soiled pads to be kept separate, and soiled ones washed for reuse, many times.

Other existing hygiene products such as tampons, washable internal cups or clip-on washable pads, were considered but rejected due to one or more of the following issues:

- Products which are inserted are not acceptable within all cultures
- Inserted products also pose a larger hygiene risk whether or not they can be washed and reused
- Clip-on pads even if washable still need underwear to work

Additionally, some suppliers reviewed or approached to explore sourcing parts of the new design were either uninterested, too small or deemed unreliable commercially.

This left one design and the need to set up a new supply chain to deliver it. The best existing design to which it could be compared was the adhesive disposable paper pads. These have absorbent paper layers with a waterproof backing, adhesive, and packaging. Although the study was conceptual there was sufficient information now available to progress with an analysis. One intention of SuReSDS™ is to allow this type of qualitative analysis which can highlight where further quantitative information is needed.

#### 3.1.4 Identify Stakeholders and Value Flows phase

To compare the different PSSs meaningfully a common basis was needed- a Unit of Analysis similar to that used in Life Cycle Analysis (Baumann and Tillman, 2004). This unit was identified as supplies for one woman for one year- also implying that one new re-useable kit must last for at least this long. The paper pads would have to include 13 sets of 12 to 20 pads for one year. In order to analyse the effectiveness of the new option against this requirement and the external best-existing system, it was next necessary to identify which people and entities (stakeholders) are significantly affected positively and negatively by the system (in this case the menstrual pads PSS) and its functions or malfunctions.

This phase applies Creating Shared Value principles (CSV, Porter and Kramer, 2011). This seeks solutions to social and environmental problems or opportunities to exploit in these areas, to gain competitive advantage by producing more sustainable strategies, products and services. This analysis was developed as a map of stakeholders to identify the flows of different types of value (including social and environmental, positive and negative) between them. The different stakeholders are viewed as belonging primarily to one of the Triple Bottom Line (TBL) categories (Elkington, 2004) of society, economy or environment; according to the main impact the system has on them. E.g., consumers are part of the economy but they hand over their economic capital (money) in order to receive a social service or product and therefore would be placed in the “society” group. The environment (local and/or global) does not in itself own money, but resources are extracted from it, and waste and pollution returned to it, as a result of the lifecycle of economic goods and services. Organisations may represent it as proxies, by passing laws, exacting fines and sanctions or applying societal pressure.

Due to the need to consider the lifecycle impacts of the PSS designs, it was decided that only direct and significant effects of the system could be included on the value flow diagram to avoid overcomplicating it. Effects on areas of the environment such as air pollution do feed back into negative health impacts on all of society; these have to be borne in mind when considering the analysis but are indirect. Both options were analysed, then compared using the value flow map shown in Figure 4. The two designs are shown photographically in Figure 5.

By considering the flows of value the system causes or enables, it is possible to come up with system designs which reduce negative impacts and improve positive ones. Effectively these are looking for more sustainable solutions by better balancing the TBL outcomes or looking for innovative synergies which benefit all areas where possible. In Figure 4 the arrows show flows of value between the stakeholders most significantly affected. The symbols show the estimated relative effect of the new design compared to the old. A + or ++ indicates a smaller or larger increase in the *magnitude* of a flow, and so on, whilst the symbols are colour coded to indicate whether this is considered a good or bad thing from the viewpoint of sustainability. +/- indicates an unclear outcome needing more work to quantify.



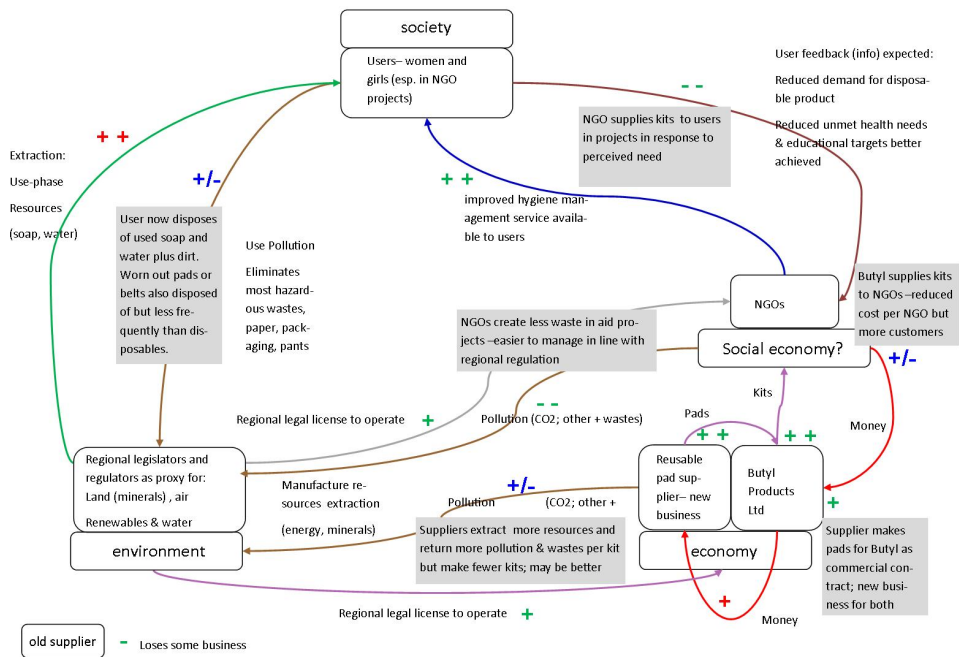


Fig. 4- Value flow map for menstrual hygiene kit comparison



Fig. 5- existing design (left, disposable sticky pads) and new design (right, washable fabric pads and belt)

It was later found that this judgement on the changes may vary according to whose viewpoint is adopted- the NGO, the supplier or the user may have a different view of economic impacts in particular, for example. One party may view them as a burdensome cost and another see them as valuable income. The assessment of social and environmental impacts so far has not been as likely to change with changing viewpoints. The diagram in Figure 3 is drawn from the viewpoint of Butyl Products, as the organisation conducting the analysis.

In this exercise a number of advantages were confirmed for the new design in reducing the major social and some environmental issues. However it also highlighted trade-offs in impacts. The new kit is likely

to be more resource-intensive per pad, using fabric, and uses soap and water to clean them; but it also uses far fewer pads in a year and very few are disposed of to the local environment or waste system. When the pads are used in aid camps they would need to be provided in tandem with washing facilities and water. Their appropriateness and associated water impact in development projects is more difficult to assess and will depend on water scarcity and other projects occurring in parallel. This is more a matter for the NGOs to consider but indicates that choices made using SuReSDS™ can be context-dependent. More quantitative information on the lifecycle impacts from each design and the changes in specific impact types, possibly in location-specific analyses would be needed to assess whether the new design represents a general improvement in environmental terms.

Other outcomes were that it is not clear whether NGOs such as charities sit in the “society” or “economy” group of stakeholders. In this case study the differing assessment of strategy effects on certain value flows was not an issue so long as the organisations (in this case both the client NGO and supplier Butyl) seek to balance the benefits and downsides to themselves and other stakeholders; and provided that all the significant stakeholders are included in the analysis. After all, Shared Value proposes exactly this balancing act for companies to become more sustainable (Porter and Kramer, 2011).

### 3.1.5 Evaluate Options Against Scenarios phase

The PSS function could now be considered in more detail to assess how its resilience can be improved. This phase uses a simplified Parameter Diagram borrowed from Taguchi’s robustness engineering (Karna and Sahai, 2012, FMC, 2011). Using the value flow diagram as the context for the PSS, different elements of its functional design, its input and outputs were identified. This also allowed consideration of feedback effects between different aspects of the system, and which parts of the system design were truly able to be altered by the organisation (Butyl).

It was now possible to define both resilience and sustainability more specifically using the Parameter Diagram. Sustainability is effectively measured within it by the ratio between all of the beneficial impacts of the outputs of the system’s function (the *desirable outputs* in Figure 5) and all of their negative impacts (*undesirable outputs*). This could be expressed using a mix of all the TBL types of value or checked by selecting only items which the strategies affect differently. All of the value flows from the previous phase appear in the diagram as one or other type of output. As before, no definite measurements for these value flows existed and only the likely effect of different strategies on these value flows could be considered.

Similarly resilience is the ability of the system to maintain this level of sustainability when disturbed by one of its inputs. This might be a *signal* (something the system is designed to respond to) or a *noise* (something it should ignore). The simplest form of resilience measure is therefore how much the output performance changes in *response to* an input changing- another ratio representing short term or innate resilience. Over the longer term the system may also *recover* and *adapt* which allows for other measures of resilience.

In this case the resilience of interest was the immediate ability of different cultures to use the hygiene kit pads. The populated Parameter Diagram is shown in Figure 5. As before the new and existing designs were compared, and the flows marked with +/- symbols using the same logic.

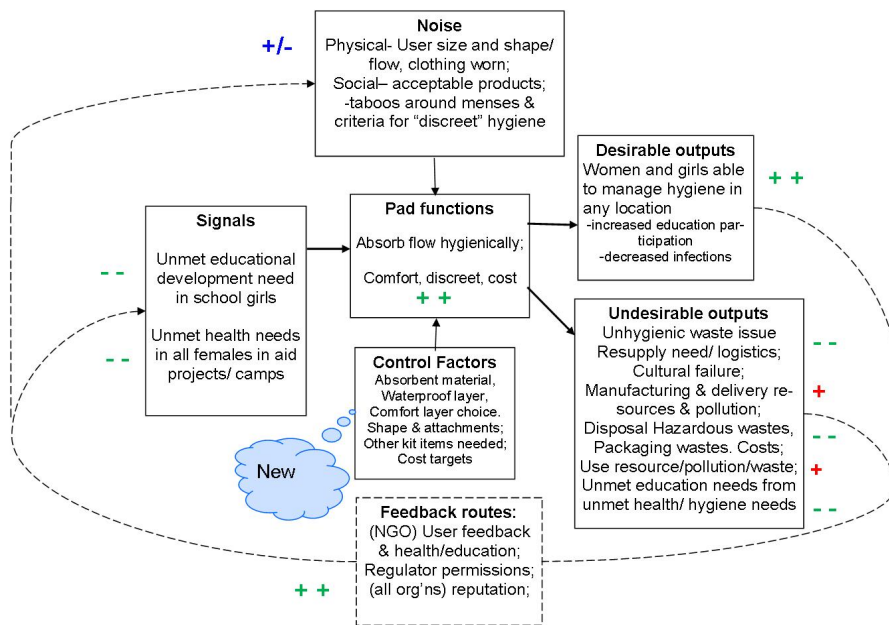


Fig. 6- System Parameter Diagram analysing function of new menstrual hygiene kit

By looking at how local culture might affect users of the pad, the resilience of the new design could be checked against these. This was effectively forming very simple scenarios of future use in the field. The main signals were the presence or not of underwear, and the new design was confirmed to work better than the old one. However other noise factors were also identified such as the size and shape of users or the intensity of flow they must manage, and these led to some improvements in the physical design and therefore function of the new PSS. The possible need for an ethical supply chain was also highlighted as a potential demand of customer NGOs. This last is probably not a concern for the users but does concern Butyl as the supplier. Figure 6 is also drawn from their perspective.

Once the strategic alternatives have been analysed, users should check that their strategies do improve the performance of the product, service or business model as needed. If not, the SuReSDS process prompts them to return to the hunt for better options. The exception is if the existing strategy is already the best available one.

### 3.1.6 Choose Option phase

Butyl Products Ltd did not have many strategic options to select between- their decision was whether to develop their design and enter a new part of their market, or not. Therefore a full comparison grid was not created. When comparing multiple strategies companies would normally use a comparison matrix adapted from Transition Engineering (Krumdieck, 2013, pp 722-728) or a version of their normal format for strategic comparisons, to select their best option.

The specialist at Butyl reported that they individually found the new approach enabled a methodical approach to a complex set of issues. It gave them confidence that they had found the best PSS design, and provided missing information to help them make a strong business case. The staff at the SME generally felt that the exercise was worth the effort and used the extra information to help specify product criteria (e.g. target costs and technical performance) develop prototypes, identify suitable suppliers and approach potential customers.

#### 4.0 Discussion of results

SuReSDS™ reproduced a description of social and environmental issues surrounding the current product, and modelled conceptually how a new product-service system (PSS) might address these. It also allowed a more detailed exploration of how the compared designs affect different stakeholders, and where the new version could improve both sustainability and resilience of the PSS. Additionally some possible negative impacts and context-specific aspects were discovered that required more investigation, to quantify any trade-offs. This allowed the advantages and disadvantages of the new design to be included in a business case and a strategy decision. Finally this study produced clear real-world impacts, assisting in the development of a new more resilient and socially sustainable product.

In terms of Figure 1 the case study succeeded in integrating sustainability and resilience thinking into organisational strategy to manage risks from both negative impacts and uncertainties. This allowed Butyl to make a strong case to customers, resulting in expressions of customer interest; which demonstrates some immediate benefits to the company.

#### 4.1 Other case study results

Two subsequent studies at Ford looked at innovative product designs using trained participants facilitated by the researcher. These showed that the approach is transferrable by training, whilst users again reported that they were better able to tackle sustainability and resilience-related strategy tasks using SuReSDS™. The information derived was used directly within their real-world projects and highlighted a number of extra opportunities and risks which they were then able to exploit or ameliorate. Further case study samples are planned at Ford, University of Surrey and the SME with trained participants, facilitated and observed by the researcher.

#### 5.0 Conclusions

SuReSDS™ appears to deliver the intended immediate benefits to decision-makers. It has affected some of the choices made in this and other case studies, by identifying new opportunities or risks and providing a methodical comparison of strategic options. If these results are supported by the other case studies the implication is that the approach is suitable for use in both large and small suppliers of PSSs, and possibly other types of organisation. One limitation however is that companies may need to import or develop sustainability and resilience expertise to be able to continue to use the approach.

Resilient Sustainability as deliverable by SuReSDS™ should therefore provide a competitive advantage to its users by allowing them to integrate sustainability into their strategy more easily and reliably than before. It allows them to look for better synergies between their economic gain and the social and environmental value they deliver to stakeholders. However SuReSDS™ has been designed for organisations which were not previously able to do this; different industries may be better or worse equipped than automotive giants and small manufacturers. It also assumes that the organisations using it wish to integrate sustainability into their decisions; any tool can of course be subverted by a different purpose than that intended. The suitability of SuReSDS™ for other sectors and more firms is one future area for research, together with exploring larger sample sizes.

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# The International Normative Socialization of Japan: Securing the Global Tuna Fishing Industry



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In March 2010, the United Nations Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which is an international agreement between governments aiming to preserve wild animals and plants engaged in international trade submitted a formal proposal seeking to ban international trade of the reportedly endangered Atlantic bluefin tuna and to have it included in the UN's list of endangered species. Although supported by the United States and Europe, this proposal was opposed chiefly, but not solely, by Japan which consumed 80% of the world's bluefin tuna catch from the Mediterranean and of the world's fresh-chilled yellowfin tuna supply. The votes having been cast in a secret ballot, the proposed ban did not prosper with 72 states disagreeing, 43 affirming, and 14 abstaining. However, in August 2013, the Japanese government expressed its intent to lead the worldwide effort of promoting the natural reproduction and recovery of the tuna species, stating that the state would reduce its tuna catches to mature ones by 15%. This paper would look into probable reasons behind the said normative change and, at the same time, explore the events which might have caused the continuous decrease in tuna catches and persistent hike in tuna prices in Japan. "Capture" (wild) and "aquaculture" (farmed) are the two types of fish production; note that only the former type was considered in this paper.

## Possible Concurrence

According to Burchill et al. (2005), Habermas's communicative action theory proposes that one of the functions of international conventions is to facilitate deliberations where the state can explain and support its behavior. These deliberations help manage conflict and thereafter arrive at a resolution which reflects the interests of *all* concerned states. At the 2010 United Nations convention, Japan refused to adopt the proposed ban arguing that, contrary to the report submitted by CITES, the tuna species were not endangered and that the International Commission for the Conservation of Atlantic Tunas (ICCAT), and *not* CITES, should be managing the conservation measures on Atlantic bluefin tuna catches. ICCAT is an inter-governmental regulatory body that oversees the world's annual tuna catch.

Burchill et al. (2005), echoing Risse, affirmed that social institutions (international organizations) acquire higher legitimacy by holding international conventions. However, as Griffiths et al. (2009) described, using Reus-Smit's view on the discursive nature of social institutions, only when the state recognizes the social institution as fair and just, and its proposed rules as ethical and moral, that the said social institution can successfully legitimize and implement new norms and rules. In this case, Japan, given its perception of CITES' identity, did not deem CITES as the authority that should be managing the Atlantic bluefin tuna, thereby disregarding the proposal.

As stated by Griffiths, Roach, and Solomon (2009), the state's consent necessary in the social institution's act of legitimizing new norms and rules can only be given if the said state can relate to the moral efficacy of the proposed norms and rules. In this case, it was probable that the domestic normative behavior compelled a continuing consciousness that Japan should maintain its custom of serving tuna recipes. This signalled to the Japanese state that it could not meet the terms of the proposal, hence the refusal to grant its consent.

## A New Identity

Three years after declining the conservation measures proposed by CITES, the Japanese Fisheries Agency (*Suisancho*), the body responsible for the state's public and private fishing industries, expressed its desire to lead the international community in promoting the conservation of tuna species. The initial step undertaken by the Japanese government was to reduce its tuna catches to mature ones by 15%. On the other hand, the National Marine Fisheries Service of the United States responsible for regulating the state's offshore fishing declared that the United States would cut its tuna catches by 25%. Since 75% of the Pacific bluefin tuna catches were consumed by Japan, and the United States was one of the major bluefin tuna catchers, these proposed conservation measures could then contribute to the recuperation of the endangered tuna species.

Constructivism proposes that state identity and interest are constantly changing; and the state acts or behaves depending on its identity and interest. As Weber (2009) argued, the state's identity is "contentious," "unstable," and "conflictual." Wendt, cited in Weber (2009), argued that the state constructs its identity in conformity with the relationships it has with other states; the constructed state identity then defines the state interest. If the state identity is not constant, then neither are the state interest and state behavior. Particularly, social constructivism looks at "the construction and regulative influence of international norms" (Griffiths et al., 2009, p. 134). In this case, Japan decided to take on a new state identity: from being the leading tuna catcher and consumer to wanting to be the leading state in promoting conservation measures on the endangered tuna species. This change in identity could have been brought about by the persistent protests by international tuna fisheries management organizations such as the Western and Central Pacific Fisheries Commission (WCPFC) and CITES, conservation groups such as Greenpeace International and World Wildlife Fund (WWF), and other fishing states like the United States and the United Kingdom, to limit its tuna catches. Japan, acting on its newly formed interest to conserve the depleting tuna stocks, had adopted conservation measures limiting its tuna catches.

## A Perception of Civilization

As previously stated, international tuna fisheries management organizations, together with conservation groups, had been lobbying Japan to limit its tuna catches and participate in the total banning of the endangered tuna species from the international trade. This, among other possible reasons (*infra*), influenced Japan in finally limiting its tuna catches and aiming for the recovery of the depleting tuna stocks.

As Hobson (2003) asserted, implying Finnemore's first level of the international structure – the normative structure, various international norms constitute the normative structure of the international society; these international norms which are always perceived to be appropriate and benevolent influence or socialize the state to act in accordance with behavioral patterns which are consequently perceived appropriate. When the state behaves properly by complying with international norms, it is then to be perceived as civilized.

Hobson (2003) further interpreted Finnemore's second level of the international structure as "surface structure" which involves international non-state actors and international organizations. These international organizations are "norm carriers" and in so being take the responsibility of informing or reminding the state how to behave appropriately. In this case, Japan had finally given in to the protests of the international organizations as regards the conservation of the tuna species by limiting its tuna catches and in so doing redeemed itself as a civilized state. The United States' statement that it would also limit its tuna catches, even beyond what Japan had set for itself, emphasized its being civilized as well; or perhaps it was trying to tell the international community that it was more civilized than Japan.

Burchill (2005) implied that since the civilized state has the tendency to feel superior to its neighboring states, it can find concluding negotiations or agreements with other states easier and more attainable. In this case, Japan might have felt superior to other states as regards tuna fishing and management, hence its proposal to lead all the other states in conserving tuna species. Moreover, though Japan's economic profit from its tuna industry would decrease and its custom of consuming tuna species would weaken as it implemented its conservation measures, its identity as the leading state in the global tuna industry and as a civilized state would be reinforced. Consequently, Japan would be perceived by other states as important and influential in concluding agreements and implementing conservation measures concerning tuna fishing. This perception of Japan by other states would entitle the former to forward its interests more conveniently through the agreements it would enter into. This, however, would not mean disregarding the interests of other states.

### **Paradigm Shift**

Interpreting Bull's perspective on maintaining "order among all mankind" belonging to a "multicultural society of states," Burchill (2005) also supposed that the state, whenever possible, should always seize opportunities that can improve the international society. Japan's decision to finally comply with international norms as regards tuna fishing, and thereby implement its own conservation measures, would be important to improving the international society. As Goldstein (1999) affirmed, fishing states should cooperate to prevent depletion of fish stocks in international waters. The state's failure to cooperate does result in reducing the catches of all fishing states.

Hobson (2003) recalled that in 1945, a remarkable normative change was undertaken by Japan which also contributed to improving the international society. With respect to its foreign policy stance or external security posture, Japan undertook a major paradigm shift from being militaristic and imperialistic to being pacifist. Since then, Japan focused on strengthening its economic sector, making the state technologically and economically advanced. These two normative changes (becoming pacifist and aiming to be the leading tuna conservator) contributed to the worldwide effort of making the international society orderly and emphasized Japan's being civilized. Considering that Japan's decision to be pacifist eventually resulted in positive political and economical consequences on the state, its decision to comply with the international norms as regards tuna fishing might also likely bring in the same on the state in the long run.

Japan's decision to finally comply with international norms as regards tuna fishing also supported Hobson's interpretations of Finnemore's claims: (1) "international forces can shape national policy" or specifically that international organizations can lead the state to constructing policies guided by international norms of behavior, (2) the international norms of behavior adopted by the state "might either fail to enhance the power of a particular actor, or might even go against the actor's power-interests," and (3) "society not anarchy, is the source of constraining and permissive effects" (Hobson, 2003, pp. 151-153). In this case, the international tuna fisheries management organizations and conservation groups (international forces) influenced Japan to construct and implement conservation measures (national policy) on the endangered tuna species. These newly constructed conservation measures would certainly lessen Japan's tuna catches, affecting the state's economic profit from the tuna fishing industry and disturbing its custom of consuming tuna recipes. In other words, the newly constructed national policy of Japan as regards the conservation of the tuna species would diminish its

economic power or hamper its power-interests. Japan's decision to conform to the norms established by the international society as regards tuna fishing would bring about *immediate* effects - economic and cultural constraints - on the state.

### An Alternative

In November 2012, the Scottish Development International and the Scotland Food and Drink instigated a trade mission in Japan. Echoing the Scottish government's claim, Richard Lochhead, Scotland's Rural Affairs Secretary, confirmed that salmon was becoming the favored choice for *sushi* in Japan, replacing tuna. He added that Scottish seafood, particularly salmon, had an exceptional ability to attract the Japanese consumer. As further pointed out by Scott Landsburgh, a chief executive of Scottish Salmon Producers' Organization, Japan was becoming known as Scotland's major salmon importer and was consistently displaying great potential as such. It was thus possible that Japan decided in August 2013 to lead the international effort of conserving tuna species and conform to international norms as regards tuna fishing because it was confident that it could nevertheless sustain its custom of consuming *sushi* and *sashimi* with another type of specie that was salmon.

This particular booming economic relationship between Japan and Scotland would benefit both states: the cultural and economic value of consuming *sushi* and *sashimi* by the former would be sustained while the value of salmon exports of the latter would dramatically increase, bringing in huge economic opportunity to the state.

As stated earlier, there could also be other reasons or events which might have influenced Japan to commit to, and even lead, the worldwide effort to recover tuna stocks. Japan is globally recognized as the leading tuna catcher and consumer. If, as asserted by D'Anieri (2012), states possessing advanced weapons systems can secure their identity as advanced states, then Japan which uses the biggest and most advanced tuna catching fleets for its tuna fishing operations can secure its identity as the leading state in the tuna fishing industry. It is also widely known that the Japanese were the ones to introduce *sushi* and *sashimi* to the rest of the world. It is then to the best interests of Japan to value its tuna fishing industry and maintain the said custom. To pursue the said interests, the tuna fishing activities of Japan are not just limited to the use of boats, or ships, or fleets; it also uses spotter planes. Given that it needs to satisfy the huge demand for tuna and that it has to operate through its advanced fishing technologies, one can just imagine how much fuel Japan needs to sustain its tuna fishing activities.

### The Ripple Effect

In June 2008, Japan decided to suspend tuna fishing operations for the next two months due to the increasing cost of fuel triggered by the political chaos in oil-producing countries. This suspension was likewise implemented by China, South Korea, and Taiwan. The chief oil for fishing fleets is called the A fuel. The table below shows how the cost of the said fuel surged from 2003 to 2008.

The A fuel per kiloliter	
Cost in Yen	Year
39,000	2003
69,000	2007
105,000	2008

Shimbun, Yomiuri. "Rising fuel costs cut down tuna fishing." *The Spokesman-Review*. June 29, 2008.

Espejo (2008) reported that Japan initially planned to halt the operations of 20% of its 20,000 tuna catching vessels; however, the said plan was only implemented on 1% or 233 of these tuna catching vessels in August, a month later than the schedule. The said suspension contributed to the international effort of recovering stocks populations of the endangered, highly valued marine resources. Since there was a decrease in tuna catches, Japan resorted to raising the prices of bigeye and yellowfin tuna. With the huge demand on tuna, Japan also had to



multiply import. Espejo (2008) further asserted that the Philippines from which Japan was a major importer radically increased its prices of yellowfin tuna.

### A Will for a Way

Other factors could have also influenced Japan’s decision to suspend tuna fishing, or at least lessen tuna catches. As reported by Foster (2013), although the proposal of CITES in March 2010 which was to ban international trade of Atlantic bluefin tuna was rejected, the said organization was able to successfully impose quotas on tuna catches for conservation purposes. Noting the efficiency of the adopted conservation measure, Masanori Miyahara, the deputy director-general of the Japanese Fisheries Agency, stated that there had been more than a quarter of reduction of juvenile catches. In 2011, Japan also complied with the conservation measures adopted by the WCPFC by limiting its tuna fishing vessels operating on the high seas. The WCPFC ensures the long-term conservation and management of highly-migratory fish stocks in the Western and Central Pacific Ocean – the region which produces 50% of the global tuna catch on an annual basis.

### Tainted Waters

In March 2011, when tsunami and earthquake struck Japan, the Fukushima Dai-Ichi nuclear plant situated northeast of Tokyo and operated by Tokyo Electric Power Co. Inc. (TEPCO) was significantly devastated, becoming the world’s worst nuclear accident following the Chernobyl disaster which happened at the Chernobyl Nuclear Power Plant in Ukraine on April 26, 1986. Radioactive particles and radiation leaks had been reported to be polluting North Asia, streaming into the Pacific Ocean. As reported by Pesek (2013), radioactive elements were subsequently found in bluefin tuna, causing the public to be suspicious of food safety and quality, thus limiting catches of the said tuna specie.

### In Demand

No one can deny that *hon-maguro*, or the business of catching bluefin tuna in Japan, is indeed a very rewarding industry. As mentioned earlier, though Japan conducts its own tuna fishing operations, it still finds the need to import from other countries such as the Philippines. Tuna products in the Philippines are categorized into four quality grades:

Philippine Tuna Quality Grades	Exported/Sold To
Sashimi grade	Osaka/Narita, Japan Seattle/Los Angeles, USA
Manila grade	refined hotels in the Philippines
Davao grade	Filipino tuna traders/sellers
General Santos grade (leftover tuna)	General Santos City folks

In 2012, a kilo of *sashimi* grade tuna sold at the General Santos City Fishing Port Complex cost US\$10; however, when the same was exported to and sold in Japan, it cost US\$1,160. According to Espejo (2012), there was even an auction held in Tokyo where tuna cost US\$2,480 per kilo. Harvey (2013) asserted that in January 2013, a bluefin tuna was sold at an auction in Japan for more than US\$10,000, followed by a report a week after stating that the bluefin tuna stocks in the Northern Pacific Ocean had declined by more than 96%. Also, Foster (2013) affirmed that in February 2013, a mature bluefin tuna was sold at US\$22,000 at Tokyo’s Tsukiji fish market. While these incidents could prove the continued demand for tuna despite its near extinction, they could also emphasize the domestic cultural value of tuna in Japan. Foster (2013) added that in the same period, Masayuki Komatsu, a former senior official of the Japanese Fisheries Agency, affirmed that Japan, being concerned about profit and culture, could not fulfil its international responsibility to conscientiously conserve tuna species – the endangered bluefin tuna could still be seen on *sushi* bars’ menu. Mr. Komatsu further revealed that the government itself, through the help of media, withheld the information regarding the depletion of tuna species and thus denied public awareness thereof.

Both tuna suppliers and consumers can barely explain how tuna prices have soared that much. As previously mentioned however, the catch limits imposed by CITES, the two-year ban on tuna fishing on Pacific Commons 1 and 2 imposed by the WCPFC, and the increase in oil prices induced tuna suppliers to impose

towering prices. We may also speculate that the increase in tuna prices is an effect of the increasing global demand for tuna, triggered by the changing diets of individuals most of whom are Chinese who now prefer fresh-chilled tuna, and by the inconsideration or ignorance of *sushi* bars with respect to tuna depletion.

### **On the Brink**

The consistent drop in tuna catches signifies the alarming condition of tuna species; different conservationist groups and international conventions held by international organizations have been asserting that tuna species are nearly extinct. The forthcoming extinction of tuna species may be strongly attributed to the use of industrial fishing techniques such as fishing down and pelagic longline fishing, consumer behavior, poor implementation of conservation measures, overfishing, and global warming.

According to the National Geographic article entitled “Overfishing,” as early as 2003, industrial fishing had already decreased the population of large ocean fish to 10% of their unscathed population. Fishing down is one of the industrial fishing techniques being practiced today which damages the seabed and destroys the balance of the biological system of the seas. Pelagic longline fishing is specifically designed to catch swordfish and yellowfin tuna; fishermen deploy onto the open seas long strings of baited hooks supported by buoys. Dolphins, turtles, and bluefin tuna are usually some of the bycatch of the said fishing method. The increasing bluefin tuna bycatch has caused the National Oceanic and Atmospheric Administration (NOAA) to restrict fishermen from loading the said tuna species, dead or alive, on their catching vessels. The NOAA disclosed that in 2012, because of pelagic longline fishing, 239.5 metric tons or about a quarter of the annual catch of the United States was a bycatch of bluefin tuna, indicating a 70% increase from that of the previous year.

According to Satran (2013), illegal fishing and bycatch are two of the main threats to the conservation measures adopted by international tuna fisheries management organizations such as CITES and the WCPFC.

Overfishing is the state of catching marine resources, consuming them before they can even reproduce. It had caused the incessant drop of catch volume of mature yellowfin tuna: 33,369 metric tons in 2007 to 9,061.13 metric tons in 2011. According to marine scientists, it was in 1989 when the world’s annual fish catch reached 90 million tons and since that time, the fish stocks have never recovered and even further declined.

According to Hood (2010), Tudela of WWF Spain stated, “Japan has the key, and the means to convince fishing countries to accept the necessary conservation measures.” Lubchenco of the US National Oceanic and Atmospheric Administration confirmed Japan’s influence on the present challenges of the international community concerning the conservation of the endangered tuna species saying, “Japan has an absolutely critical role to play.” In August 2013, as Japan finally disclosed to the international community its interest to conserve the endangered tuna species, granted that it would efficiently implement the conservation measures it had constructed and act upon the role it had claimed to execute, positive and favorable changes concerning the conservation of valued tuna species would not be far behind.



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# The Real Cause for the US Subprime, Financial, Economic Crises in 2007-2009



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## **Abstract**

This paper is devoted to investigate the real cause of the US subprime, financial, economic crises. It will first review related literature, and then examine a number of key economic factors related to oil production and consumption. The resulting insight will help answer the question on the impacts of ARRA because the knowledge of the fundamental cause of these crises will help determine what the most effective solutions to the economic recovery should be and examine if ARRA succeeded to deliver these solutions.

## **Introduction**

Since the 2008 global economic crisis, economic and financial theorists and practitioners have widely discussed and acknowledged the lax economic and financial regulations and legislations as structural problems of the existing US and global economy that allowed mounting economic and financial risks to be overlooked and to have directly triggered the global financial and economic crisis. However, studies on some of more fundamental issues, such as rising energy prices and climate change, their relationship to the

carbon-based global economy's consumption of fossil fuels, especially of oil, and their relationship to the global financial and economic crisis, were scarce and largely ignored.

This study will examine the US economy's dependence on the consumption of carbon-based energy sources, especially oil. It will also investigate several related key indicators, including energy consumption per unit of GDP for selected economies, world GDP, world energy consumption, world oil price, and US delinquency rate.

## Literature Review

There was a consensus that the collapse of the housing market triggered the 2007 US financial crisis. Major factors identified as leading to the boom and bust of the housing market included subprime lending, government regulation in expanding home ownership through mortgage subsidies for impoverished borrowers, monetary policy in the United States and Europe, corporate pay structures, credit-default swaps, banks' leverage, lax financial deregulation, etc. (Acharya, Philippon, Richardson, and Roubini 2009; Bordo 2009; Caballero and Krishnamurthy 2009; Reinhart and Rogoff 2008; Acharya and Richardson 2010; Caballero, 2010; Mian and Sufi 2010; Mayer 2011).

However, studies exploring the relationships between the rising oil prices and the housing and financial crisis in 2008 were scarce and largely ignored. These studies explored the issue from two main perspectives, with one focusing on the causes of the housing boom and the other focusing on what caused the collapse of the housing market.

One of the popular explanations of the housing boom between 1996 and 2006, in which real housing prices rose by 53 percent, was easy credit in the form of low real interest rates, high loan-to-value levels and permissive mortgage approvals. If this explanation were valid, then the financial crisis could be considered less a systemic or structural problem of the US and world economy. Improved monetary and financial mechanisms would be capable of preventing this kind of irrational housing bubble in the future. However, if easy credit was not the primary culprit of the housing bubble, then more research is necessary to investigate what actually caused housing first to boom and bubble and then to collapse and burst to trigger the financial crisis.

Glaeser et al. disputed the low interest rate and easy credit explanations. Their study reexamined the housing prices and found that the predicted impact of interest rates on housing prices is much lower once the standard user cost model of housing prices is generalized to include mean-reverting interest rates, mobility, prepayment, elastic housing supply, and credit-constrained home buyers. This theoretical impact of interest rates on prices was found in line with their empirical estimates. Based on this study, the authors concluded that low real interest rate can explain only 20 percent of the price increase of the housing boom. The study did neither find convincing evidence that changes in approval rates or loan-to-value levels could explain the bulk of the housing boom. The authors pointed out the need of "better corrections for the endogeneity of borrowers' decisions to apply for mortgages" (Glaeser, et al., 2010).

Other studies focus on what caused the housing bubble to burst. Carr and Beese (2008) found a moderate correlation between the rise in interest rates and the rise in oil prices between 2004 and 2007, which led to home foreclosures between 2005 and 2008. Theramus (2009) found that volatility in the oil prices caused the financial crisis in 2008. Hamilton (2009) reviewed several approaches (Blanchard and Gali, 2007; Edelstein and Kilian, 2007; Blinder and Rudd, 2009) to estimating the impact of oil price shocks on the economy, including some methods that had previously shown an economic decline following previous oil price shocks.

Hamilton further explored similarities and differences between the run-up of oil prices in 2007–08 and the earlier oil price shocks. He found that different from previous oil price shocks, which had been primarily caused by physical disruptions of supply, the price run-up of 2007–08 was caused by "strong demand confronting stagnating world production" (Hamilton, 2009). His observation seemed to concur with the

view of a growing number of studies that world oil production has reached its peak (Campbell and Laherrère, 1998; Almeida and Silva, 2009; Höök et al., 2009; Shafiee and Topal, 2009; Zhao et al., 2009).

At the same time, he observed that despite the different causes of soaring oil prices, the 2007–08 oil shock had the same economic depressing consequences as the previous oil shocks, for the economy in general and for consumption spending and purchases of domestic automobiles in particular, which caused home market crash, severe financial and economic crises, and economic recession. He concluded that the increase in oil prices in the period of 2007 through 2008 had made a “material contribution” to the subsequent US financial crisis (Hamilton, 2009).

Sexton et al. also found in their recent empirical study that high gas prices caused the US housing bubble to burst (2012). Their study went beyond the mainstream economists’ view that blamed the US housing collapse in 2007 for inducing a financial crisis that spread to the entire economy and causing a severe and prolonged economic downturn.

The authors investigated the role of skyrocketing gas prices and a dramatic gas price shock in triggering the housing market collapse. They did this by developing a model of housing demand that integrates the Alonso-Muth urban model and the Poterba model of housing investment. The Alonso-Muth urban model showed that, in equilibrium, suburban residents are compensated for increased commuting costs by lower land prices. The Poterba model was used to simulate the likely effects of gas prices on house prices.

The authors showed how low gas prices had first fueled the housing boom along with low interest rate, easy access to credit, and new mortgage products, which made suburban housing affordable to high leveraged and long work commuting homebuyers who were otherwise low credit worthy because of low incomes.

The study showed how the persistently rising and subsequently skyrocketing gas prices, which doubled between 2005 and 2008, then increased the costs of commuting between suburban homes and workplaces in city centers and the costs of distant, commuting-based suburban living, and forced the vulnerable homeowners to abandon their commuting lifestyle. The authors concluded that suddenly rising commuting costs lowered the values of distant homes away from the city centers and made them undesirable, and caused rising foreclosure rates.

This view was echoed by Anderson (2009) who argued that the recent financial crisis was largely caused by the long-term problem of the current world economy lacking a sustainable path of development. He based his findings on the theory of “limits to growth” – expressed principally through rises in the price of oil and other commodities – created a crisis for the global financial system, which essentially assumes an indefinite economic growth. These findings supported an increasing public recognition of and increased calls for the need for sustainable development (Strange and Bayley, 2008), a development pattern that “meets the needs of the present without compromising the ability of future generations to meet their own needs” or meets “the needs of the present while contributing to the future generations’ needs” (Needham, 2011).

## **Examinations and Results**

Drawing on the existing studies that link the recent financial crisis to the conflict between the US-led world economy’s oil dependence and the recent changes in the world oil market, this study will examine the relationship between the recent economic and financial crises and the problems of the US economy.

To pin point more exactly the impact of oil price surges on the United States and other developed economies, the study investigated these economies’ respective oil dependence (Fig. 1) from two perspectives—the one concerning the oil consumption as a share of the respective economy’s total primary consumption and the other concerning the correlations of the growth of the world economy and the growth of the world oil consumption.



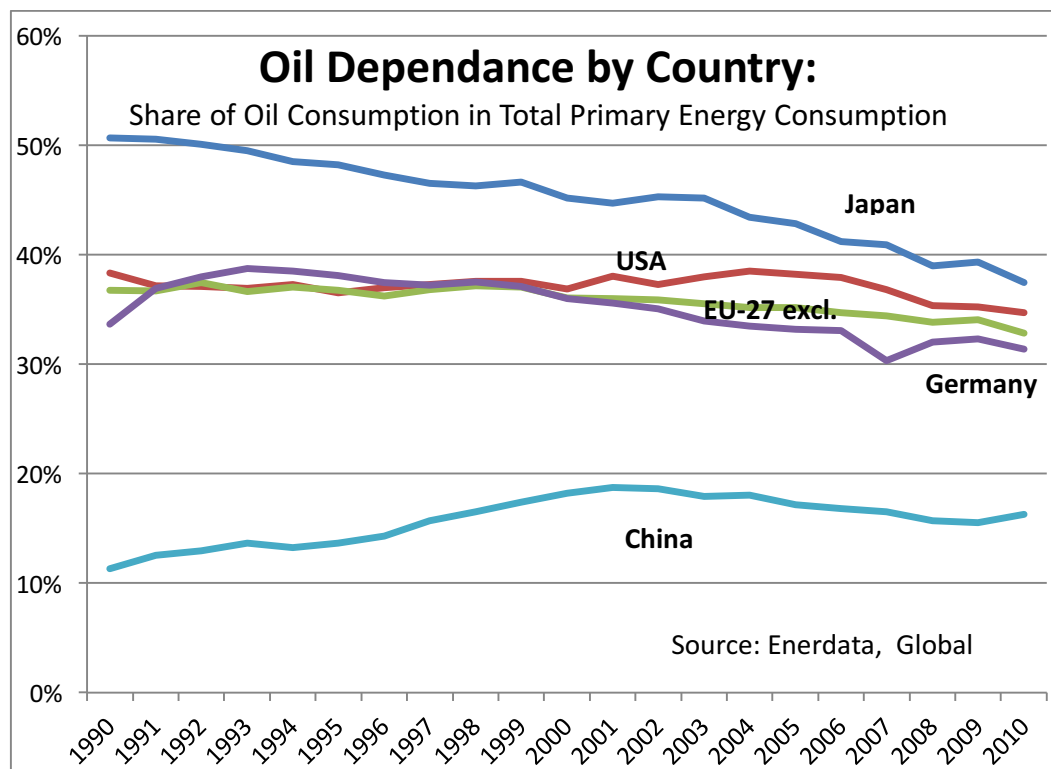


Fig. 1 Oil Dependence of Major Economies (Data Source: Enerdata, 2011)

The results of the investigation showed both a promising trend of reduced oil dependence and a concerning reality of high oil dependence of the major developed economies. On the one hand, the major developed economies' oil dependence experienced a notable reduction, with a 14 percent decrease from 51 percent in 1990 to 37 percent in 2010 in Japan, and a three percent decrease respectively in the United States, Germany and other EU-27 countries in the same period. On the other hand, the developed economies still displayed significant oil dependence between 31-37 percent. While the reduced oil dependence was induced by high oil prices and the gradual advancement of renewable energy, the persistently high oil dependence of the United States and other major developed economies made them particularly vulnerable in the face of volatile oil markets and rising oil prices.

A sectorial analysis of the US oil dependence revealed an even depressing picture. While the economy-wide oil dependence in the United States was only around 35 percent in 2010, the oil dependence in manufacturing and transportation were much higher: 43 percent and 96 percent respectively. While the overall high oil dependence explained well why US economy was especially vulnerable to soaring oil prices, the extremely high oil dependences of the key economic sectors manufacturing and transportation in the United States made it self-explanatory why the oil price hikes in 2007-2008 damaged, as Train and Winston (2008) observed, these economic sectors most severely.

The examination of the long-term oil production and oil consumption relation revealed an interesting two-factor trend. On the one hand, the world oil demand has been steadily increased from approx. 1500 megatons in 1965 to approx. 4000 megatons in 2011, a 167 percent increase. On the other hand, while the oil production was able to offer a sustained supply surplus over the oil consumption in the long period from 1965 to 2000, this surplus turned into a frequent supply shortfall since then. This two-factor trend indicated the difficulty the world oil production had to meet the increasing world oil consumption, which explained well the continuously rising oil prices (Fig. 2).

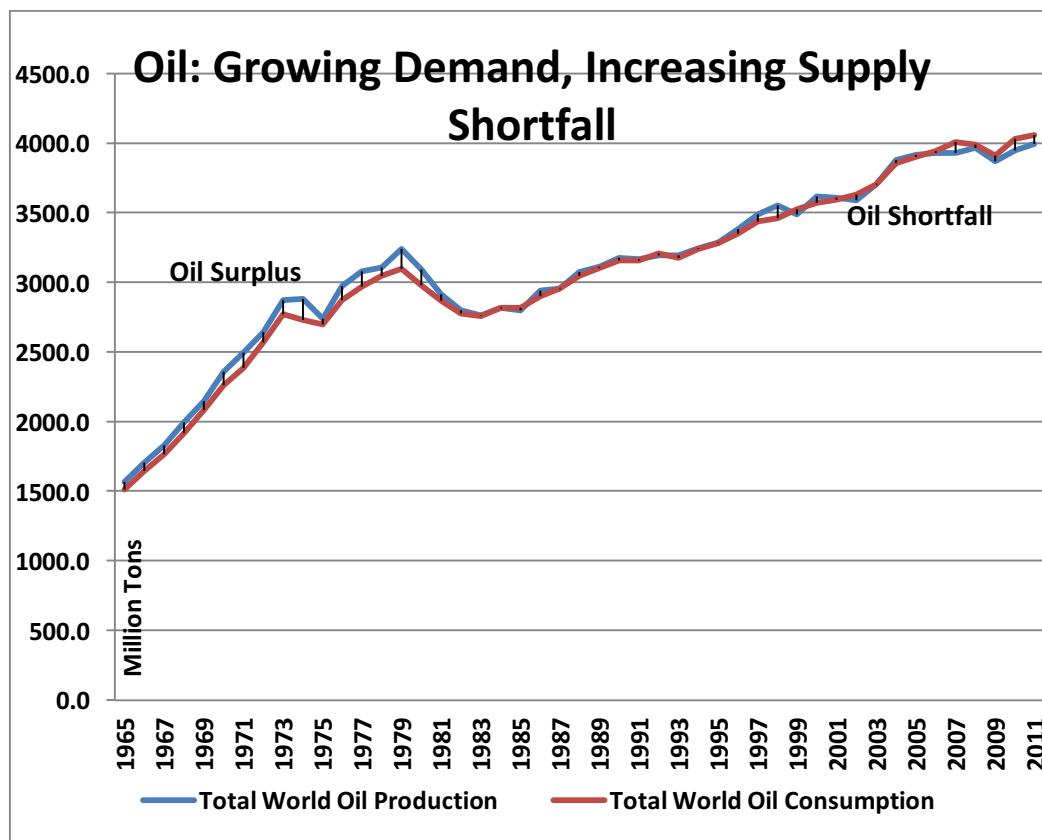


Fig. 2 Rising Oil Demand: From Supply Surplus to Supply Shortfall (Data Source: BP, 2012)

The composition examination of the world oil consumption showed two interesting observations. First, the oil consumption of the major developed economies such as the United States, the EU, and Japan still constitutes a major share of the world oil consumption. Second, the increase of the oil demand did not come from these major developed economies, but came rather from other countries, especially from the rapidly developing countries such as China and India (Fig. 3).

Considering the size of population and the further developing needs in these developing economies, their demand for oil represented On the one hand a strategic approach to energy consumption because of oil's less environmental and ecological impact than that of the major energy source in these countries—coal. However, this increased oil demand called for an inevitable oil supply shortfall and rising oil prices in the face of insufficient oil production since the turn of the new millennium. The correlation coefficient of .46 between the oil supply shortfall and the rising oil prices in the period between 2002 and 2011 showed that the rising oil prices in this period were closely related to the short supply in the world oil markets.

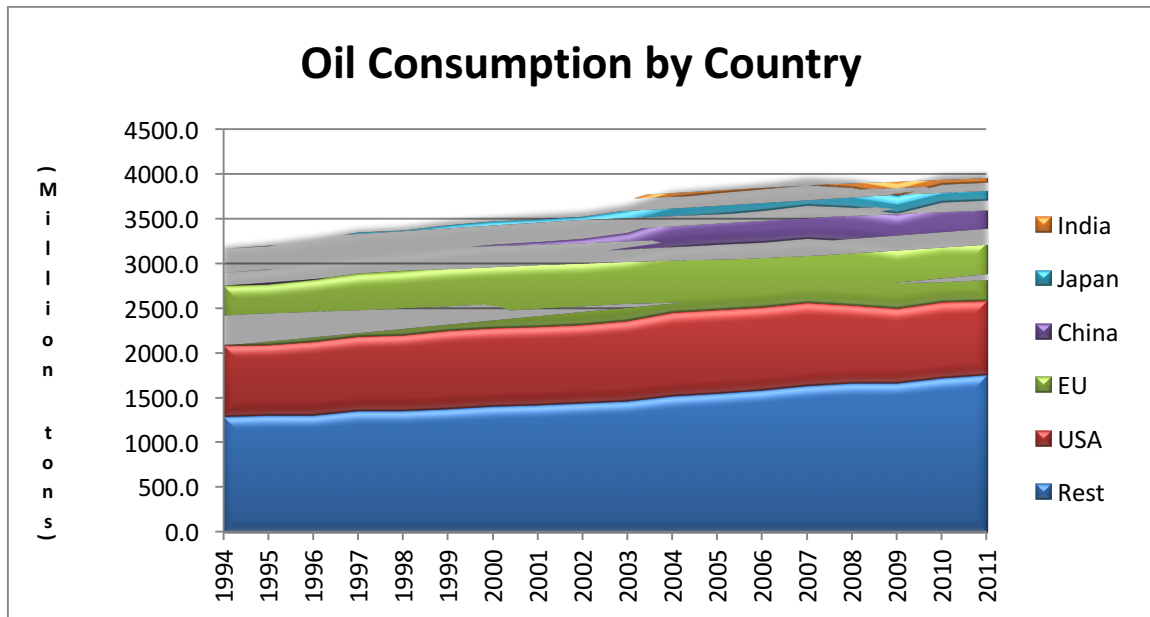


Fig. 3 Oil Consumption of Major Economies (Data Source: BP, BP Statistical Review of World Energy 2012)

The investigation of the correlations of the growth of the world economy and the growth of the world oil consumption revealed that the current world economy was highly oil dependent. The growth in the world GDP and the change in the world oil consumption showed a high correlation (.79). The world economy's high oil dependence informed us that, in the absence of other significant alternative energy sources, the any GDP growth would further intensify the world economy's oil demand and oil consumption. However, the US economy had an even higher oil dependence of .85, much higher than other major economies, which indicated that the world biggest economy was also the world's most oil dependent major economy in the last 20 years (Fig. 4).

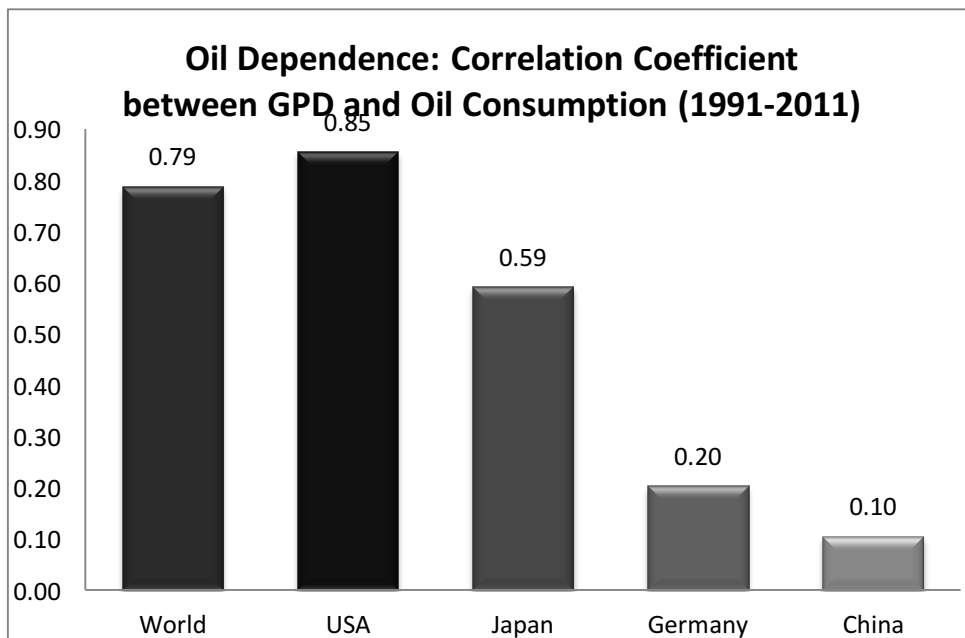


Fig. 4 Oil Dependence Measured by Correlation between GDP and Oil Consumption in 1991-2011 (Data Sources: World Bank, 2012; IMF, 2012; BP, 2012)

Based on this basic investigation of the oil production and oil consumption in recent years, this study compiled and analyzed data related to the growth in the world GDP, the world oil consumption, the increase in world oil price index, first mortgage default index; and decline in the US auto sales.

Fig. 5 shows the dynamic impact of skyrocketing oil price since 2002 the US economy in general and on the US first mortgage delinquency rates and the US auto sales in particular before, during, and after the US economic crisis. As a long term trend, rising oil prices already caused the mortgage default rate to rise sharply before the 2007 US financial crisis. In this period, the US auto sales also felt the strong downward pressure caused by the oil price rises and kept a gradual downward trend from 2004, several years before the economic crisis.

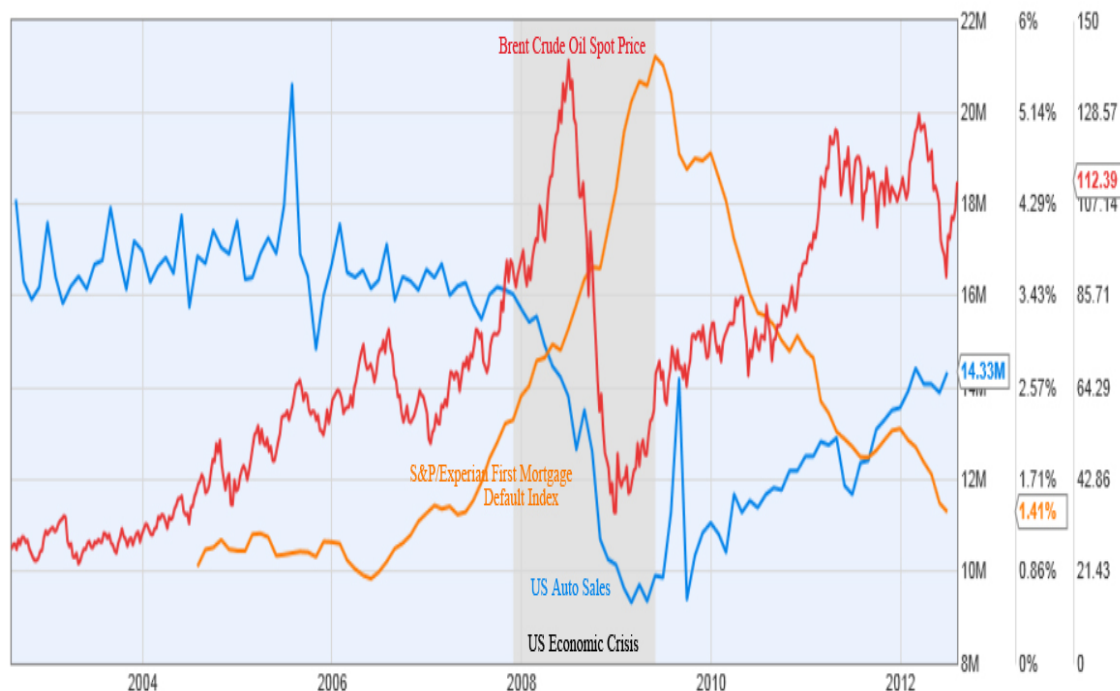


Fig. 5 Oil Price, US Mortgage Default, US Auto Sales, and US Economic Crisis (Data Sources: BP, 2012; S&P/Experian, 2012; Autodata, 2012)

During the US economic crisis, both the surge in the US mortgage delinquency rates and the drop in the US auto sales were intensified, which constituted a sharp contrast to the rigid oil price hike. The continued skyrocketing oil price lasted for a month, despite the strong market signal of a dramatic economic downturn, until it reached its record high and plunged into a free fall to the 2004 price level.

The rigid oil price hike at the beginning of the economic crisis contributed to forcing the mortgage default rate to surge to a record high and the US auto sales to drop to a record low during the economic crisis. This insensitive upward movement in the oil prices can be read as its “overreaction” to the oil supply shortfall caused by the growing oil-dependent world economy. The continued surge in oil prices even during the early months of the economic crisis was paralleled, with a delay, by the continued surge in US delinquency rate. This observation confirms the findings of Carr and Beese (2008) and the assumption made by Anderson (2009) and Hamilton (2009) that there is a positive relationship between the rises in the oil price and the financial crisis.

Although the mortgage delinquency flood did not reverse its rising trend and the US auto sales did not reverse its plunge until the economic crises was over, the oil price started already to rise again before the economic crisis was over.

## Conclusions

This study investigated the relationship between the rising oil prices and the economic crisis in the United States. The investigation found a substantial relationship of the US economy's high oil dependence as its structural weakness and economic and financial vulnerability and the rising oil prices since 2004 and skyrocketing oil price hikes in 2007 as the primary culprit of the 2007 US financial crisis and the subsequent US and global economic crisis and the long-term financial constraint of the oil-dependent US and global economy.

The findings of this study suggest the need of the transition from the carbon-based economy to a greener and more sustainable economy and the need to develop and implement a comprehensive green economic transformative strategy. Such a transformation can play a significant role in proactively dealing with the financial constraint of the future economic growth, and allow the US and global economy to grow in an economically and financially more sustainable and healthy manner.

Certainly, the recent financial crisis was immediately triggered by the mortgage crunch as a result of the subprime lending and related "shoddy" subprime lending practices. However, one should not ignore the economic factors that caused the housing bubble and subsequently the housing bust on the one hand, and the fatal impact of oil price surge on housing market in particular and on the overly oil dependent US economy in general. In other words, we must see what caused the mortgage crunch to trigger the financial crisis. As the expansion of the world GDP and the increase in oil demand and oil supply shortfall fueled oil price hikes, the skyrocketing oil prices, in turn, put significant strain on US living, manufacturing, and transportation in terms of rising costs (World Bank, 2012), related job markets (rising unemployment rate), and financial markets (subprime market bust).

To be sure, the drastic drop in oil prices during the financial and economic crisis was only a temporary phenomenon as a result of substantially reduced energy demand in response to the contracted size of the wasteful and inefficient carbon economy. Now that the existing carbon-based economy returns to "business as usual," the hard financial constraint, as we now are witnessing, has started haunting the economy again and causing the economic recovery to take place at a painfully slow pace. As matter of the fact, the resurged high gas prices are constraining the US economic recovery in general and the recovery of the US oil-dependent sectors such as manufacturing and transportation, as well as housing markets in particular. The latter is especially true for distant houses that are associated with high commuting costs.

If the current still relatively "low" oil prices were mistaken as a turning point from the long-term oil constraint and rising oil prices, the US economy could sadly miss the opportunity of switching over to a greener sustainable economy based on increased renewable energy generation and reduced oil dependence. To sum up, in addition to the US mortgage crunch as the direct trigger of the 2008 global economic crisis, this study found the rising oil prices as the main culprit of the US mortgage, financial, and economic crises in 2007-2008. In addition, the study found the carbon-based, oil-dependent energy structure of the US economy, especially its key economic sectors manufacturing and transportation, as the one of the main reasons for the severity of the US mortgage, financial, and economic crises caused by the skyrocketing oil prices and the difficulty of the US economic recovery.

Based on these findings, this study concludes that without a green transformation that significantly improves the efficiency of fuel consumption and the carbon-based, oil-dependent energy structure of the US economy and the other major economies, the US led global economy will not be able to avoid the fundamental contributing factors of the recent economic crisis and frequent future economic crises it will be facing: soaring energy prices, pollution and climate change, and the global financial mess. As Pavan Sukdhev pointed out, the carbon-based "economic models of the 20th century are now hitting the limits of what is possible" (UNEP, 2008).

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# An Assessment of the Productive and Environmental Efficiencies of Japanese Industries



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## **Abstract**

The global warming and climate change becomes a major policy issue in the world. To partly deal with the climate change issue from economics and business concerns, this study proposes a use of Data Envelopment Analysis (DEA) as a methodology for unified (operational and environmental) assessments. The proposed DEA approach has been long serving as an important methodology to evaluate the

performance of various organizations. Recently, many researchers have applied DEA to various environmental issues. A contribution of the previous DEA studies was that they found the importance of an output separation into desirable (good) outputs and undesirable (bad) outputs (e.g., CO<sub>2</sub> emission and air pollution substances from production activities). Acknowledging a contribution of these previous studies on DEA environmental assessment, this study classifies efficiency measures into the two categories according to the treatment of undesirable outputs: (a) productive efficiency and (b) unified efficiency under natural disposability. The first efficiency does not incorporate undesirable outputs in the performance evaluation, while the second measure incorporates them to the environmental assessment. Using a data set regarding the manufacturing industries of 47 prefectures in Japan, this study examines their productive and environmental efficiencies to obtain policy implications. The important empirical finding suggests that Japanese regional industries need to make their further efforts to reduce air pollution substances and increase energy efficiency.

## **1. Introduction**

After the two oil crises in the 1970s, Japan diversified its energy sources through an increased use of nuclear energy, natural gas and coal to reduce the dependency on oil. Manufacturing industries, representing a majority of energy consumption in Japan, have worked on progressing energy conservation and improving energy efficiency. It is known that Japan has few energy resources, so depending on import for 96% of its primary energy supply. Even the nuclear generation is considered as domestic energy, the energy import dependency is still at 82%. Despite the efforts for energy conservation and increasing energy efficiency, oil still accounts for about 40% of Japan's primary energy supply and most of them come from the politically unstable Middle East region. As a result, the Japanese energy supply structure is vulnerable. See Energy White Paper [1].

Since the Great East Japan Earthquake in 2011, such efforts have become more important than before because all nuclear units stop their operations with an exception of only two units in 2013. Approximately 90% of electricity consumption in Japan is produced by fossil fuel power plants. Such conditions resulted in a tight relationship between demand and supply on electricity and increased import of fossil fuels from abroad. Currently Japan faces a major policy change on the energy that is directed towards more renewable resources and less dependency on nuclear power generation. The Japanese government has begun a new policy discussion on Basic Energy Plan regarding a future desirable energy mix.

Along with a shift to the new energy mix after the earthquake in 2011, Japan needs to pay attention to the climate change and global warming in the world. Since the Kyoto Protocol came into effect in 2005, Japanese government promoted environmental policy to reduce GHG (Greenhouse Gas) emissions from

a use of fossil fuels. The manufacturing industries are important contributors to the growth of Japanese economy and they have been major contributors for Japanese regional economy. Meanwhile, they are major producers of GHG emissions such as CO<sub>2</sub>. In 2011, industry sector as a whole accounts for approximately 34% of CO<sub>2</sub> emission. That is the largest among all sectors for the amount of CO<sub>2</sub> emission, although its share gradually decreases over time. The introduction of CO<sub>2</sub> emission trading scheme had been discussed, but that is not yet determined in Japan.

However, there is a voluntary institution within Japanese industries that continues to promote environmental protection. To achieve the environmental protection goals through global competition, the industries need to improve their productive efficiency and to satisfy environmental requirements in such a manner that they can balance between them for the development of a sustainable society. Under such a business condition, technology innovation in production is essential for Japanese industries. The technology innovation, arising from environmental constraints, is usually associated with an environment-friendly, energy-efficient production system, as discussed by Porter and van der Linde [2]. They stated that corporate efforts for improving the productivity of an entire manufacturing process under environmental regulations resulted in both improving productivity and environmental protection. The assertion is often referred to as “Porter Hypothesis” in corporate strategy.

The purpose of this study is to examine the productive and environmental performance of manufacturing industries in 47 prefectures (local government units in Japan which correspond to states in the United States). The examination reveals the importance of improved energy efficiency and environmental protection for the manufacturing industries in Japan to attain higher performance. In this study, the achievement of Japanese industries is measured by their unified (operational and environmental) efficiencies. For the research purpose, this study proposes a new use of DEA (Data Envelopment Analysis) environmental assessment, in which desirable and undesirable outputs are combined together under a disposability concept related to environmental strategy. See, for example, recent studies [3,4] for innovative uses of DEA in the area of energy policy and economics.

The remainder of this paper is organized as follows. Section 2 describes DEA environmental assessment as a managerial methodology for enhancing the productive and environmental performance of industries. Section 3 exhibits a data set regarding the manufacturing industries in the 47 prefectures. Section 4 summarizes our empirical results and discusses related policy implications. Section 5 concludes this study along with future research extensions.

## 2. Methodology

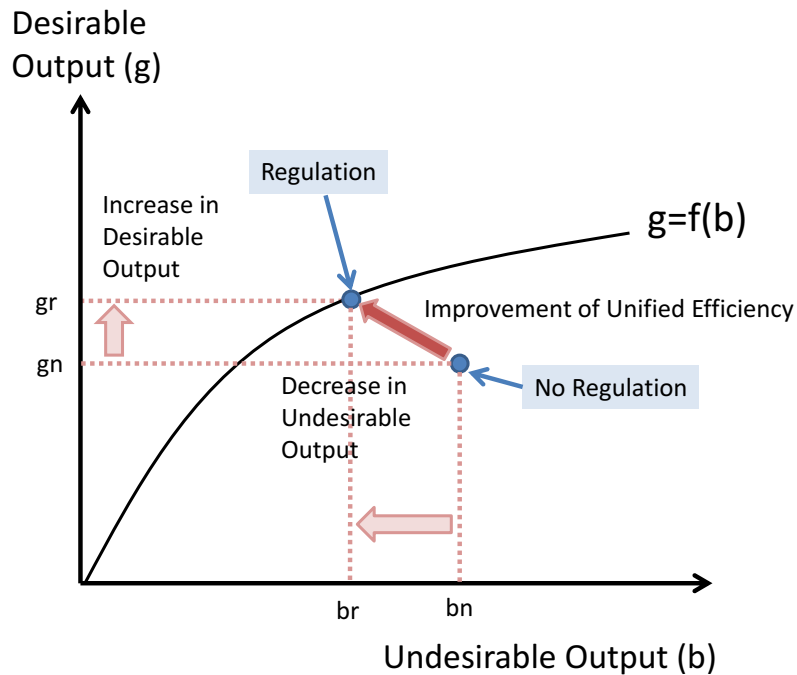
### 2.1 Previous Efforts on DEA Environmental Assessment

To combat the climate change, many previous studies proposes DEA as a methodology for environmental assessment. See, for example, [5-15] and many other articles published in the past decade. As discussed in the previous efforts, DEA was originally developed as a managerial methodology to evaluate the performance of various organizations in public and private sectors. A contribution of the previous studies in environmental assessment was that they separated outputs into desirable and undesirable ones. An important issue to be considered is how to unify these different outputs to assess the performance of organizations from their production and environmental concerns. See [15] that summarized more than 100 articles in environment and energy studies. As a result of their contributions, DEA environmental assessment can serve as an empirical methodology for planning and developing a sustainable society where economic prosperity can coexist with environmental protection. This study will fully utilize the research wisdom explored in the previous studies.

### 2.2 Natural Disposability

To discuss DEA environmental assessment, this study needs to describe a strategic concept related to environmental protection [16-18], which is referred to as “natural disposability”, indicating that an organization decreases the directional vector of inputs to decrease the directional vector of undesirable outputs. Given the reduced vector of inputs, the organization increases the directional vector of desirable outputs as much as possible. This study considers the natural disposability as a negative adaptation to a change on environmental regulation because it does not invest for technology innovation but decreases inputs to cope with government regulation on undesirable outputs.

Figure 1 visually describes the relationship between desirable and undesirable outputs under natural disposability. The functional form ( $f$ ) is expressed by  $g = f(b)$  where  $g$  and  $b$  stands for desirable (good) and undesirable (bad) outputs. The figure depicts the natural disposability to respond to a regulation change on an undesirable output. As in Figure 1, an organization reduces the amount of an input to decrease the amount of an undesirable output (from  $b_n$  to  $b_r$ ) until it satisfies the level of an undesirable output that is required by governmental regulation. Under the condition, the organization tries to maximize the desirable output as much as possible (from  $g_n$  to  $g_r$ ) under natural disposability to enhance its productive and environmental unified efficiency.



**Figure 1: Natural Disposability**

As discussed above, the concept on natural disposability originates from corporate strategy to adapt a regulation change on undesirable outputs. The natural disposability responds negatively to the regulation change because it does not invest in the production system for introducing technology innovation. This study is fully aware of an existence of other strategic alternatives in which firms respond positively to the regulation change by considering it as a new business opportunity, or they shift production facilities to a region and a country with less environmental regulation. However, this study excludes such strategic alternatives and focuses on the negative adaptation to the regulation change.

Finally, using an axiomatic expression, production technology to express natural disposability is formulated by the following two types of output vectors and an input vector, respectively [17, 18]:

$$P^n(X) = \left\{ (G, B) : G \leq \sum_{j=1}^n G_j \lambda_j, B \geq \sum_{j=1}^n B_j \lambda_j, X \geq \sum_{j=1}^n X_j \lambda_j, \sum_{j=1}^n \lambda_j = 1, \lambda_j \geq 0 \right\}.$$

In the axiomatic expression, this study considers  $n$  DMUs (Decision Making Unit, e.g., corresponding to an organization in private and public sectors).  $X \in R_+^m$  is an input vector,  $G \in R_+^S$  is a desirable output vector and  $B \in R_+^h$  is an undesirable output vector of each DMU. The subscript ( $j$ ) stands for the  $j$ -th DMU and  $\lambda_j$  indicates the  $j$ -th intensity variable ( $j = 1, \dots, n$ ) that connects data points to construct a convex hull (part of an efficiency frontier) in a data domain.



### 2.3 Productive Efficiency

This study starts with describing a non-radial model to measure productive efficiency, or *PE* of the  $k$ -th DMU. Since this study employs the non-radial measurement, the level of inefficiency is determined by slacks. The operational efficiency does not consider an influence of undesirable outputs in the efficiency measurement, which is thus based on the fundamental framework of conventional production economics. The *PE* measure regarding the  $k$ -th DMU is obtained by the following non-radial model [19]:

$$\begin{aligned}
 & \text{Maximize} && \sum_{i=1}^m R_i^x d_i^x + \sum_{r=1}^s R_r^g d_r^g \\
 & \text{s.t.} && \sum_{j=1}^n x_{ij} \lambda_j + d_i^x = x_{ik} && (i = 1, \dots, m), \\
 & && \sum_{j=1}^n g_{rj} \lambda_j - d_r^g = g_{rk} && (r = 1, \dots, s), \\
 & && \sum_{j=1}^n \lambda_j = 1, \\
 & && \lambda_j \geq 0 \quad (j = 1, \dots, n), \quad d_i^x \geq 0 \quad (i = 1, \dots, m), \\
 & && \text{and } d_r^g \geq 0 \quad (r = 1, \dots, s).
 \end{aligned} \tag{1}$$

The two production factors are expressed by  $X_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T$  and  $G_j = (g_{1j}, g_{2j}, \dots, g_{sj})^T$ . The superscript “ $T$ ” indicates a vector transpose. It is assumed that  $X_j > 0$  and  $G_j > 0$  for all  $j = 1, \dots, n$ , where the inequality is applicable to all components of the two vectors.

Slacks regarding inputs and desirable outputs are specified by  $d_i^x (i = 1, \dots, m)$  and  $d_r^g (r = 1, \dots, s)$ , respectively in Model (1). A column vector of intensity variables are expressed by  $\lambda = (\lambda_1, \dots, \lambda_n)^T$ .

They are used for connecting the input and output vectors by a convex combination. Since the sum of structural variables is restricted to be unity in Model (1), the production possibility set is structured under variable RTS (Returns to Scale).

The data ranges ( $R$ ) in Model (1) are determined by the upper and lower bounds of the two production factors. They are specified as follows:

$$\begin{aligned}
 R_i^x &= (m + s)^{-1} \left( \max \{x_{ij} \mid j = 1, \dots, n\} - \min \{x_{ij} \mid j = 1, \dots, n\} \right)^{-1} \text{ and} \\
 R_r^g &= (m + s)^{-1} \left( \max \{g_{rj} \mid j = 1, \dots, n\} - \min \{g_{rj} \mid j = 1, \dots, n\} \right)^{-1}.
 \end{aligned}$$

After solving Model (1), the level of *OE* is determined by

$$\theta^* = 1 - \left( \sum_{i=1}^m R_i^x d_i^{x*} + \sum_{r=1}^s R_r^g d_r^{g*} \right). \quad (2)$$

Here, slacks within the parentheses are obtained from optimality of Model (1).

## 2.4 Unified Efficiency under Natural Disposability

The research of [17, 18] has proposed the following model to measure the unified efficiency (*UEN*) of the *k*-th DMU under natural disposability after incorporating a vector of undesirable outputs or  $B_j > 0$  where

$$B_j = (b_{1j}, b_{2j}, \dots, b_{hj})^T:$$

$$\begin{aligned} \text{Maximize} \quad & \sum_{i=1}^m R_i^x d_i^x + \sum_{r=1}^s R_r^g d_r^g + \sum_{f=1}^h R_f^b d_f^b \\ \text{s.t.} \quad & \sum_{j=1}^n x_{ij} \lambda_j + d_i^x = x_{ik} \quad (i = 1, \dots, m), \\ & \sum_{j=1}^n g_{rj} \lambda_j - d_r^g = g_{rk} \quad (r = 1, \dots, s), \\ & \sum_{j=1}^n b_{fj} \lambda_j + d_f^b = b_{fk} \quad (f = 1, \dots, h), \\ & \sum_{j=1}^n \lambda_j = 1, \\ & \lambda_j \geq 0 \quad (j = 1, \dots, n), \quad d_i^x \geq 0 \quad (i = 1, \dots, m), \\ & d_r^g \geq 0 \quad (r = 1, \dots, s), \quad \text{and} \quad d_f^b \geq 0 \quad (f = 1, \dots, h). \end{aligned} \quad (3)$$

Since Model (3) measures unified (productive and environmental) efficiency, undesirable outputs are incorporated into the model. Slacks regarding undesirable outputs are specified by  $d_f^b (f = 1, \dots, h)$ . Using the upper and lower bounds of inputs, desirable outputs and undesirable outputs, their data ranges are specified as follows:

$$\begin{aligned} R_i^x &= (m + s + h)^{-1} \left( \max \{x_{ij} \mid j = 1, \dots, n\} - \min \{x_{ij} \mid j = 1, \dots, n\} \right)^{-1}, \\ R_r^g &= (m + s + h)^{-1} \left( \max \{g_{rj} \mid j = 1, \dots, n\} - \min \{g_{rj} \mid j = 1, \dots, n\} \right)^{-1} \text{ and} \\ R_f^b &= (m + s + h)^{-1} \left( \max \{b_{fj} \mid j = 1, \dots, n\} - \min \{b_{fj} \mid j = 1, \dots, n\} \right)^{-1}. \end{aligned}$$

Model (3) considers only negative deviations  $d_i^x (i = 1, \dots, m)$  to attain the natural disposability where all inputs decrease to improve the productive efficiency of the *k*-th DMU, while satisfying the regulation requirement on undesirable outputs. A unified efficiency score ( $\theta^*$ ) of the *k*-th DMU under natural disposability is measured by slightly modifying Equation (2), so becoming

$$\theta^* = 1 - \left( \sum_{i=1}^m R_i^x d_i^{x*} + \sum_{r=1}^s R_r^g d_r^{g*} + \sum_{f=1}^h R_f^b d_f^{b*} \right), \quad (4)$$

where the inefficiency score and all slack variables are determined on optimality of Model (3). The equation within the parenthesis, obtained from the optimality of Model (3), indicates the level of unified inefficiency under natural disposability. The unified efficiency is obtained by subtracting the level of inefficiency from unity.

### 3. Data

Table 1 summarizes descriptive statistics of Japanese manufacturing industries. This study considers three inputs to produce both a desirable output and four undesirable outputs. The three inputs are the amount of labor, capital, and energy. The labor, as an input, is determined by the number of employees multiplied by the index of working hours, which is standardized by year 2000 (unit: index). The amount of capital, as another input, is a capital stock of private-sector firms multiplied by the rate of operation regarding capital assets, standardized by year 2000 (unit: index). The amount of energy is the final energy consumption (unit: 1,000 Terajoule).

A desirable output is the real GPP (Gross Prefecture Product, unit: 100 billion yen). Four undesirable outputs are the amount of carbon emissions (unit: 10,000 ton Carbon), SO<sub>x</sub> emissions (unit: 100 kNm<sup>3</sup>), NO<sub>x</sub> emissions (unit: 100 kNm<sup>3</sup>) and dust emissions (unit: 10 ton per annual).

All data sets constitute for each 47 Japanese prefecture for the year 2002, 2005 and 2008, each of which is related to manufacturing industries and non-manufacturing industries.

The data sources are as follows. The number of employees and the capital stock of private-sector firms are from the regional database of CRIEPI (Central Research Institute of Electric Power Industry). The index of working hours is obtained from the survey on a work force by Ministry of Internal Affairs and Communications and the monthly survey on labor statistics by Ministry of Health, Labor and Welfare. The index of rate of operation on manufacturing industries is obtained from statistics of rate of operation regarding capital for mining and manufacturing industries, prepared by Ministry of Economy, Trade and Industry. The data source concerning the amount of final energy consumption is the energy consumption statistics for each prefecture, prepared by Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry.

**Table 1: Descriptive Statistics of Manufacturing Industries**

Outputs and Inputs		Desirable Output	Undesirable Outputs				Inputs		
Variables		Real Gross Prefecture Product	Carbon Emissions	SOx Emissions	NOx Emissions	Dust Emissions	Labor	Capital	Energy
Unit		100 Billion JPY	10,000 ton Carbon	100 kNm3 (kilo-newton per cubic-meter) per Annual	100 kNm3 (kilo-newton per cubic-meter) per Annual	10 ton per Annual	Index	Index	1,000 Tera Joule
2002	Avg.	22.3920	178.9503	25.0987	52.1242	83.8218	23.1470	69.3575	138.4510
	Max.	114.4226	1678.2387	138.5414	241.4170	336.1282	102.8552	341.4123	1031.8996
	Min.	1.9242	3.4962	0.8447	3.6130	3.4280	2.8959	6.6641	9.6391
	S.D.	24.0486	314.6423	28.5836	51.7796	80.0926	23.2401	68.2247	192.4770
2005	Avg.	26.6152	175.1315	22.2721	53.5589	80.9142	22.8297	78.4672	138.1335
	Max.	139.1626	1669.7059	107.2844	252.7304	353.3633	101.1612	398.2985	1026.8958
	Min.	1.9366	2.7995	1.0402	4.4471	3.9850	2.9795	7.7023	10.5616
	S.D.	28.5525	311.9574	23.8799	53.0294	81.2209	22.7059	77.0281	192.4507
2008	Avg.	27.9972	157.1507	16.1879	41.1374	64.8745	22.4823	77.5445	126.3314
	Max.	129.2511	1417.4103	75.2500	234.1000	296.4000	98.9933	402.2377	883.1531
	Min.	2.0585	2.5986	0.3300	1.0800	2.2000	3.1571	7.6103	10.9340
	S.D.	28.4268	274.4460	17.2381	46.3464	67.1028	22.1069	75.4925	170.6623
Total	Avg.	25.6681	170.4108	21.1862	48.9402	76.5368	22.8197	75.1231	134.3053
	Max.	139.1626	1678.2387	138.5414	252.7304	353.3633	102.8552	402.2377	1031.8996
	Min.	1.9242	2.5986	0.3300	1.0800	2.2000	2.8959	6.6641	9.6391
	S.D.	27.0024	298.9037	23.8197	50.4152	76.3195	22.5280	73.2690	184.2389

The real GPP is obtained from prefecture economic accounts prepared by Cabinet Office. The amount of carbon emissions is obtained from energy consumption statistics for each prefecture by Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry. The data source of other undesirable outputs: (a) SOx emissions, (b) NOx emissions, and (c) dust emissions; is the survey of air pollution substances conducted by the Ministry of Environment.

Table 1 indicates that the real GPP of Japanese prefectures increases over the observed period, while all undesirable outputs such as carbon emissions and two inputs (i.e., labor and energy) decrease during the same period in the manufacturing industries. An amount of capital increases over the observed period. This indicates that the Japanese manufacturing industries make their corporate efforts to improve their operational and environmental performance by decreasing the amounts of labor and energy inputs and increasing the amount of capital to introduce technology innovation.

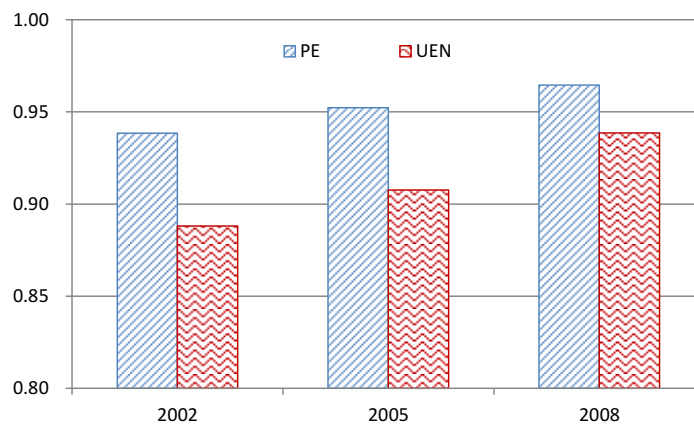
## 4. Empirical Results

### 4.1 Efficiency Measures

Table 2 summarizes the two types of efficiency measures regarding manufacturing industries, which are measured by Models (1) and (3), respectively. Figure 2 visually describes the average efficiency in the three annual periods.

**Table 2: Results of *PE* and *UEN***

Industries	Manufacturing Industries			
Year	2002	2005	2008	Total
Statistics	Productive Efficiency (PE)			
Avg	0.9384	0.9522	0.9646	0.9517
Max	1.0000	1.0000	1.0000	1.0000
Min	0.6860	0.7072	0.8331	0.6860
S.D.	0.0680	0.0605	0.0413	0.0583
Statistics	Unified Efficiency under Natural Disposability (UEN)			
Avg	0.8880	0.9076	0.9385	0.9114
Max	1.0000	1.0000	1.0000	1.0000
Min	0.4885	0.5155	0.7106	0.4885
S.D.	0.1189	0.1071	0.0754	0.1035



**Figure 2: Efficiency Measures of Manufacturing Industries**

The findings from Table 2 and Figure 2 are summarized as follows: First, two efficiency measures increased from 2002 to 2008. For instance, *PE* increased from 0.938 to 0.965 and *UEN* from 0.888 to 0.939 for the manufacturing industries in the three annual periods. This indicates that Japanese

manufacturing industries made the corporate efforts for improving their performance on productive and unified efficiency. Second, the result indicated that the efficiency scores became lower when undesirable outputs, or environmental factors, were incorporated into the proposed DEA assessment. Furthermore, *PE* had the smaller variation among prefectures in a similar level of efficiency, than *UEN*. The result implied that manufacturing industries in all Japanese prefectures made similar level of efforts for improving their productive performance. In other words, the productive and environmental unified performance of Japanese manufacturing industries was less important than their productive performance.

#### 4.2 Sources of Inefficiency

In this section, this study is interested in what production factors are sources of the inefficiency explored in Section 4.1. Since this study employs non-radial DEA models, each slack is related to each production factor and the slack directly links to a level of inefficiency. Thus, it is possible for us to identify the sources of inefficiency by examining the level of slacks regarding production factors. To explore the research concern, this study measures a ratio of each adjusted slack to the total sum of adjusted slacks. For example, the inefficiency related to each input  $i$  ( $i = 1, \dots, m$ ) is expressed by

$$R_i^x d_i^{x*} / \left( \sum_{i=1}^m R_i^x d_i^{x*} + \sum_{r=1}^s R_r^g d_r^{g*} \right) \text{ for Model (1), and}$$

$$R_i^x d_i^{x*} / \left( \sum_{i=1}^m R_i^x d_i^{x*} + \sum_{r=1}^s R_r^g d_r^{g*} + \sum_{f=1}^h R_f^b d_f^{b*} \right) \text{ for Model (3).}$$

The denominator of the above ratios indicates the level of inefficiency, which is expressed by the second term of the right-hand side of Equations (2) and (4), respectively.

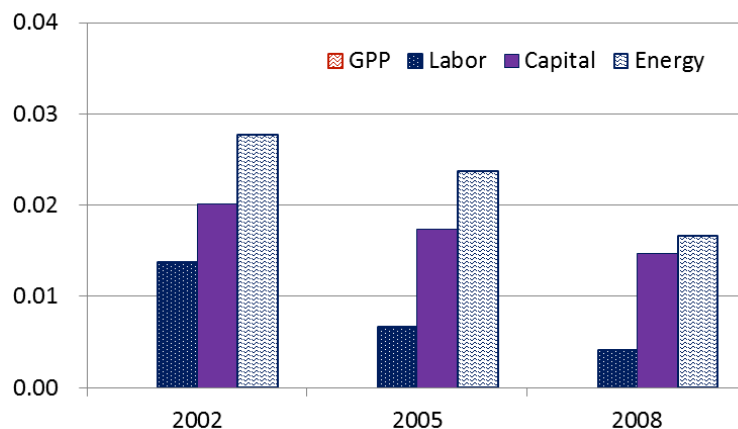


Figure 3: Slacks Used to Measure Productive Efficiency Measures

Figure 3 visually describes the average of each adjusted input slack to “productive inefficiency” from



2002 to 2008 on the manufacturing industries. The magnitude of the vertical axis in Figure 3 is standardized on the range from 0 to 0.04.

Figure 3 depicts that an amount of energy is the largest production factor to produce the productive inefficiency. This indicates that the level of energy efficiency is important for their operational performance.

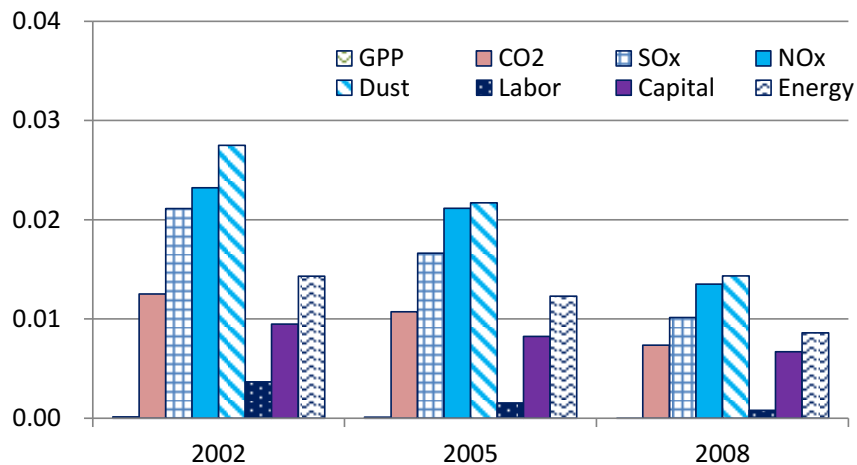


Figure 4: Slacks Used for Measuring Unified Efficiency under Natural Disposability

Figure 4 shows an annual change of slacks used to measure unified efficiency under natural disposability (*UEN*) on the manufacturing industries. It is easily found in Figure 4 that four undesirable outputs (i.e., CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub> and dust emissions) dominate their unified inefficiency measures. The amounts of energy and capital still explain a significant part of unified inefficiency. Therefore, the reduction of undesirable outputs and capital, and the improvement in energy consumption are important measures for regional manufacturing industries to attain a high level of unified (productive and environmental) performance. Figure 4 visually describes that the manufacturing industries in some prefectures attain a high level of unified efficiency by controlling their undesirable outputs, energy and capital.

In summary, undesirable outputs produce a large difference in efficiency measures among prefectures, because some prefectures successfully manage the reduction of undesirable outputs, while the others do not. Such a difference among prefectures is also due to their energy and capital usages.

#### 4.3 Regional Differences in Efficiency Measures

The data set used in this study consists of Japanese 47 prefectures. They are geographically classified into

nine regions from north to south: (a) Hokkaido, (b) Tohoku, (c) Kanto, (d) Chubu, (e) Kinki, (f) Chugoku, (g) Shikoku, (h) Kyushu and (i) Okinawa.

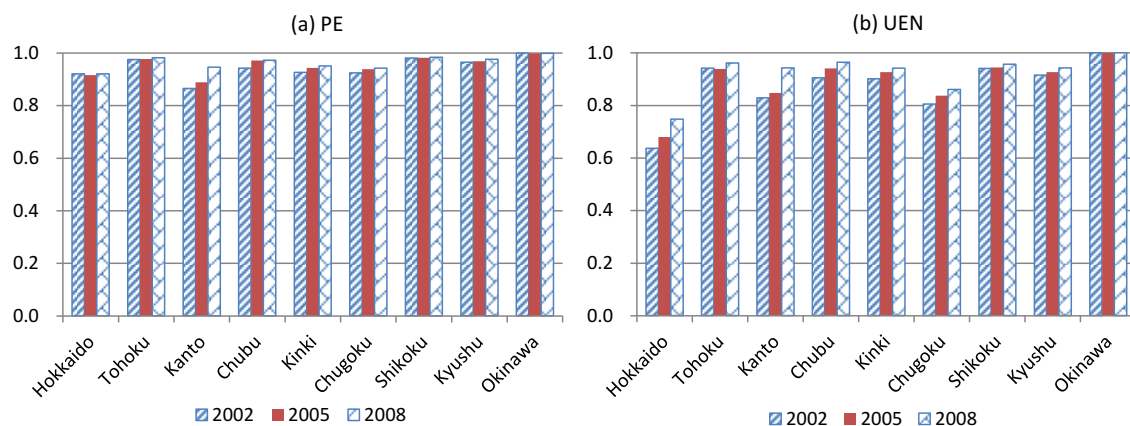


Figure 5: Regional Differences of Efficiency Measures in Manufacturing Industries

Figure 5 depicts the productive efficiency ( $PE$ ) and the unified efficiency measure ( $UEN$ ) of the nine regions. The left hand side of Figure 5 is related to the  $PE$ . The right hand side is for the  $UEN$  for the manufacturing industries.

The two efficiency measures exhibited different patterns among nine regions. For example, the regional variation on  $PE$  was relatively small, but the  $PE$  of Hokkaido was slightly lower than that of the other regions, whereas the other regions were almost same in the level of the  $PE$ . Shifting our interest from  $PE$  to  $UEN$ , the regional variations of  $UEN$  were larger than those of  $PE$  as discussed in Section 4.1, although there was a similar trend between  $PE$  and  $UEN$ . That is, Hokkaido was the lowest among the regions, followed by Chugoku with respect to both  $PE$  and  $UEN$ . The lower efficiency measures in Hokkaido and Chugoku implied that these areas may have a future potential to improve their unified efficiency measures by changing their industrial structures.

## 5. Conclusion

This study proposed the DEA models for the two efficiency measures such as  $PE$  and  $UEN$ . This study applied them to a data set, consisting of Japanese manufacturing industries in 47 prefectures. The measurement of  $PE$  did not incorporate undesirable outputs whereas those of  $UEN$  incorporated undesirable outputs in their assessments.

This study found four empirical results, which were summarized as follows. First, the  $PE$  and  $UEN$  in the

manufacturing industry indicated an efficiency improvement from 2002 to 2008. Second, the level of efficiency decreased when the DEA model incorporated undesirable outputs. In particular, four undesirable outputs were major sources of inefficiency in *UEN*, which indicated there were wider variations among prefectures on controlling undesirable outputs, compared to the management efforts for increasing desirable outputs. The desirable output did not make a similar level of inefficiency. Meanwhile, the amount of energy was the largest source of inefficiency in *PE*. It also explained a large part of inefficiency in *UEN* for manufacturing industries. Third, the amount of capital caused a certain level of inefficiency in *UEN* of the manufacturing industries. Finally, Hokkaido and Chugoku were lower than the other regions in terms of efficiency. The difference in efficiency measures of the two regions with the others are larger in *UEN* than *OE*.

These findings suggest Japanese regional industries need to make their further effort to reduce air pollution substances. The improvement can be achieved by investing in technology innovation. Such an effort requires a certain amount of capital for the investment. In addition, it is true that the investment takes a time until its result appears, depending upon the condition of macro economy, an investment cycle and other regional factors. In particular, the manufacturing industries in Hokkaido and Chugoku have potential to improve their productive and environmental performance by introducing technology innovation. This study did not examine such a positive adaptation of industries to the regulation.

Although this study examined *PE* and *UEN* regarding Japanese regional industries, their industrial structures were different among regions. Each region has its intrinsic industrial structure. The difference influences the level of efficiency measures concerning each region, particularly when the assessment included environmental factors such as GHG emissions. Thus, it is necessary for this study to investigate the relationship between the level of efficiency measures and the industrial structure of regions. That will be an important future research task.

Finally, it is hoped that this study makes a contribution on DEA environmental assessment and Japanese regional study. We look forward to seeing future research extensions as discussed in this study.

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