Sufficient Community Development and Co-Management Institutions for Sustainable Energy Management: A Case Study in Thailand

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Abstract

This paper examines the main principles underlying of bioregion, community based natural resource management CBNRM, renewable energy (RE), and how to put it together for energy sufficient community development. This participatory research approach was conducted to 4 nationwide seminars in Thailand. The results from seminars were used for developing the action model for driving energy sustainable community development (ESCD). The fact findings roughly support the idea that community demand engagement fosters more favorable local views of sufficient community development.

Keywords: community based natural resource management, energy autonomy, energy sustainable community, renewable energy

1. Introduction

Thailand's support policies for renewable energy (RE) in the power sector have allowed individual small projects to add up to something substantial, attracting more investment and leading to faster growth in the sector than in most other Asian nations (World Economic Forum, 2013). Thailand was among the first countries in Asia to introduce incentive policies for the generation of electricity from renewable energy (RE) sources, leading to rapid growth (Lutz, 2013). Thailand is one of the first countries in Asia to have a policy to encourage biofuels, cogeneration, distributed generation, and the generation of power from RE. Although Thailand has a large amount of agriculture raw materials for the production of ethanol and biodiesel for the last few decades, fuel choice is extremely diverse (World Economic Forum, 2013). Apart from the usual fuels of bagasse, paddy husk and woodchips, the government has seen proposals to use many other types of biomass, biogas, municipal wastes and solar energy . However, in year 2012, Thailand has only 1.5 % of RE in total of Thailand's Power Generation Mix, as illustrated in Fig. 1.

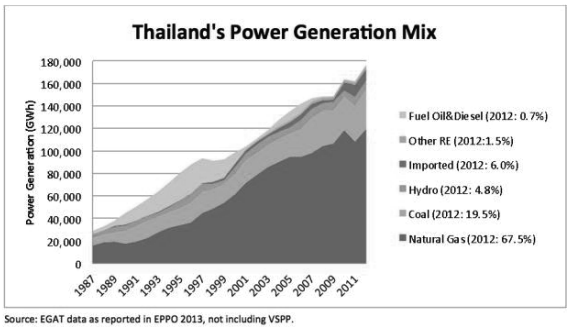

Fig. 1. Thailand's report on power generation mix

Thai government passed the 15-year Renewable Energy Development Plan (2008–2022), setting a target of achieving 20% of RE in final energy consumption. At the end of 2011, the 10-year Alternative Energy Development Plan (2012–2021) increased these targets to 25% in total energy consumption and 10% in electricity consumption (Cheokul, 2012). However, the current RE technological plan and achievement, in year 2011, seems to be missing target objectives, as demonstrated in Fig. 2. Only solar and biogas were achieved the target objective.

Definitions

1.1 *Biogas* is principally a mixture of methane (CH_4) and carbon dioxide (CO_2) along with other trace gases. These natural sources of biogas include: aquatic sediments, wet soils, weeds or plant energy, industrial wastewater, buried organic matter, animal and insect digestive tracts, and in the core of some trees (DEDE, 2014).

1.2 *Biomass* is biological material derived from living, or recently living organisms. It most often refers to plants or plant-

based materials which are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel (DEDE, 2013).

1.3 *Biodiesel* is a form of diesel fuel manufactured from vegetable or plant oils, animal fats, or recycled restaurant greases. Domestically produced from non-petroleum, renewable resources (DEDE, 2014).

RE Technology	2011 Target, MW	Actual 2011 Capacity, MW	Difference, %
Solar	55	110.97	+101.76%
Wind	115	0.38	-99.67%
Small/Micro Hydro	165	13.28	-91.95%
Biomass	2,800	724.72	-74.12%
Biogas	60	98.69	+64.49%
Waste (MSW)	78	37.33	-52.14%
Total	3,273	985.37	-70%

Source: Tongsopit and Greacen 2012.

Fig. 2. The current RE technological plan and achievement

Thailand has a single policy of energy cost, e.g. electricity bill, gas LPG or NGV, diesel and gasohol oil, no matter urban or rural areas, they must pay the same price. In addition to the rising cost of the energy, many of the rural communities are also facing inefficiencies in the energy management of the limited supply available (Chuenchom & Chris, 2004). These energy management issues include limited education about energy conservation, poor maintenance of the energy currently available, and lack of communication between communities about the availability of new sources of energy, particularly community based natural resources. In order to address these community based natural resource management (CBNRM) issues, the Senate Standing Committee on Energy and co-management institutions have supported energy sustainable communities in switching to alternative energy sources and educating people about energy conservation methods (Roseland, 2000). Thailand has currently taken measures in order to reduce their energy dependence on fossil fuels and supply its communities with alternative of CBNRM. The CBNRM programs seek to achieve the trial objectives of biodiversity conservation, utilized and optimized local resources, and poverty alleviation (Helen, 2013), (Piers, 2006).

From secondary data, interviewing, seminars (group focus), and surveying inhabitants, researcher was tried to identify the social and economic factors that influenced how rural communities fulfilled their energy needs. These fact findings permitted researcher to take into diagnosis the socio-economic characteristics of these energy sustainable communities and these deliberations were applied to inform stakeholders about result's recommendations for energy sustainable community development (ESCD) and presented to The Senate Standing Committee on Energy.

2. Aims

The objectives of this paper are identified the social and economic factors, and ecosystems that influenced how rural communities fulfilled their energy needs;

2.1 To study the rising cost of energy coupled with increased debt, how is it created a problem for these communities

2.2 To study the factors that influenced energy self-sufficiency in community energy projects

2.3 To create the model of co-management institutions for sustainable energy communities

In this paper, researcher investigate for complement and supplement to this emerging technological set of critiques and attempts to improve the practice of CBNRM through a particular focus on institutions as conciliators of community-environmental relations.

3. Theory, concept of the research and related findings

Thailand has to mostly depend on energy import e.g., crude oil, natural gas, coal, electricity. The statistic from the year 2011 shown that over 60 percent of primary commercial energy demand derived from importation. Alternative energy development will reduce dependency and import crude oil, natural gas, and other energy resources, moreover it helps sharing the risk in providing fuel for power generation which previously relied on natural gas at over 70 percent (DEDE, 2013)..

Renewable energy is a natural source of electricity (biomass) and gas (biogas) for rural communities because it is convenient, safe,

environmentally friendly, costs effective and can often be built near the community that will be using them (Cai & et al, 2009). It is highly sustainable energy derived from community based natural resources. How to build energy autonomy of sustainable community is the concept of this research paper. The word autonomy alludes to the conception of self-reliance, but also refers to liberation, or independence from external control or influence (Muller & et al, 2011). When referred to energy, autonomy can consequently be described as the ability of an energy system to function fully, without the need external support in the form of energy imports throughout its own local energy generation, storage and distribution system (Kaldellis, Zafirakis, & Kavadias, 2009). This idea is also defined to as energy self-sufficiency (Callum, & Fiona, 2012). The scale of community development is principal to how energy autonomy is planned, determined, and administrated the design, construction, operations, and future fade-out of any sustainable community development. The concept of bioregionalism is diagnosed as a method of elucidating the scale in autonomous energy project (Sale, 2000). Bioregionalism is a way of investigating subject to the feasibility of the world in naturally defined bioregions, which are envisaged as the optimal scale for human, technology, resource development, and financial support, as presented in Fig. 3. The bioregions provide natural resource boundaries, and place an emphasis on human dependency upon CBNRM (Melissa, Robin, & Ian, 1999). This concept has obvious connection to energy autonomy, as each bioregion needs to be capable of supporting its resident inhabitants, on the other hand, community development must not stave an extent which cannot be supported by the bioregion resources.

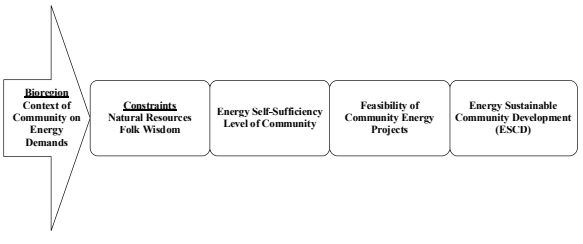

Fig. 3. The order transition for revision on bioregions

The transition to sustainable community links a broad range of social, economic, technical, engineering disciplines, and community partici pation. With transformations in project scale come changes in the number and range of stakeholder involvement, appropriated local policy, local resources available, financial available, techno logical and knowledge available and decision making processes available, as depicted in Fig. 4.

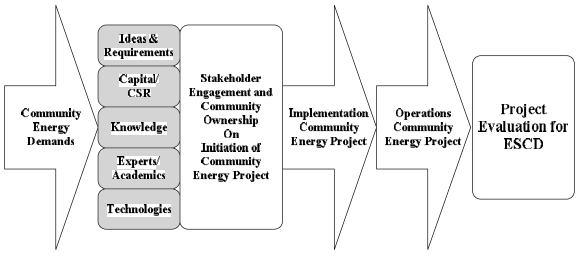

Fig. 4. The transformation of project scale in energy autonomy

The governments of developing countries have come under pressure with the effect that their energy policies and strategies highlight the need to shift away from traditional fuels towards RE e.g. biomass, biogas, biodiesel, solar energy, hydro-power, thermal energy, tide, wind (Meyar-Naimi & Vaez-Zadeh, 2012). A transform into a nice enforcement, sustainable RE sector requires a theatrical change in attitude, perception, behavior, commitment and the willingness of interrelated stakeholders to participate in this transfer process (Steve & Stefan, 2009). For that reason, the represent interrelationship model needs to be formulated for common understanding throughout stakeholders during transition mechanism, as presented in Fig. 5; potential roles, functions and responsibilities of these stakeholders clustered into the three categories of Shapers (central and local governments), Facilitators (donor agencies, NGOs, research organizations) and Implementers (commu nities, private sector) (Steve & Stefan, 2009).

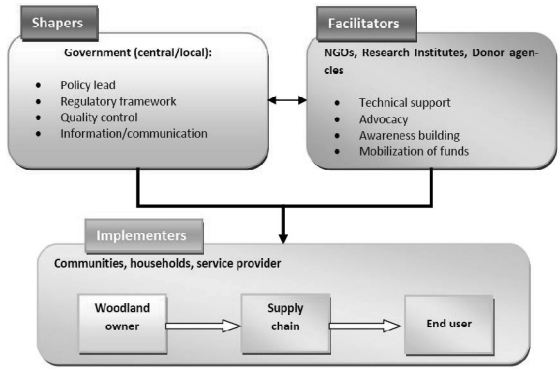

Fig. 5. The roles and potentials of different stakeholders

4. Methodology

A participatory action research method was used for this study by setting 4 seminars distributed to all regional universities (Ilan, (2001), Kasetsart University (Central), Khon Kaen University (Northeast), Chiang Mai University (North), and Prince of Songkla University (South) of Thailand during January 2014 to February 2014. Each seminar was concentrated on stakeholders that direct involved with energy sustainable community development (ESCD) by during each seminar researcher has 4 topics and 4 sections for discussions and critiques as follows;

1. Direction of energy self-sufficient communities in Thailand
2. Promote energy policies for self-sufficiency and community development
3. Reduce costs, increase revenue from potential of community energy
4. The development of community energy self-sufficient

To ensure that the populations were representative of a diversity of community/social groups, thus the subjects included The Senate Standing Committee and Sub-Committee on Energy (15), central government representatives from energy sector (15), National Research Council of Thailand (NRCT) (2), academic sectors (10), and local government representatives from energy sector (10), and community representatives (50-100). The expectation of each seminar has participants around 100-150 people, as presented in Fig. 6.

All recommendations and suggestions from 4 seminars were recorded and reported to Thailand Senate Subcommittee on Energy and Consider Promoting Energy Self-Sufficiency and Community Development for gathering and consolidating SCD prototypes. The Senate Subcommittee on Energy will report to The Senate Standing Committee on Energy for handle this report as practice recommendations for issue the new energy policy act to support SCD.

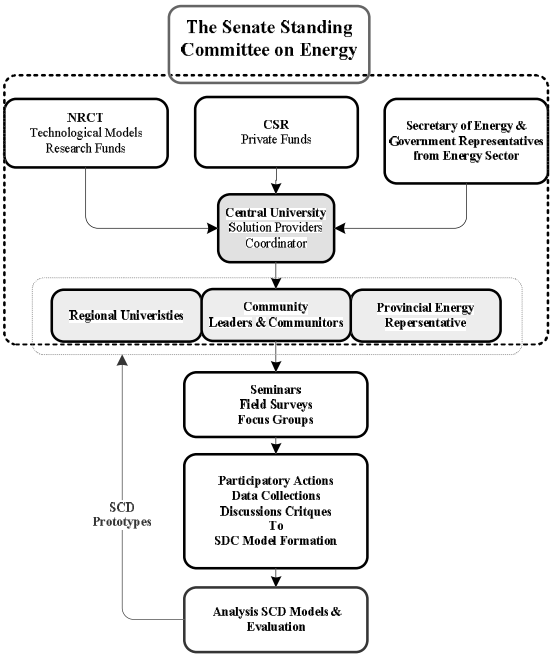

Fig. 6. Research methodology and data collection

5. Results

The fact findings from 5 seminars revealed crucial factors; community demand on energy need to be analyzed and fulfilled by local energy resources with proper technologies and good consultants; community energy policy must be driven up from local community not driven down from central government; each community energy project must be engaged and owned some share by community; incubation process or ESCD model needs be supported by central government through a new renewable energy ACT. Data collection and recommendations from each seminar are passed through Senate Sub-Committee on Consider and Promoting of Energy Self-Sufficiency and Community Development. The group of Sub-Committee is working closed with NRCT and Kasetsart University to form an ESCD model.

The government energy policy is determined from central, which do not come from the needs of the local community. Therefore, the direction of energy self-sufficient policy proposed shall be from the local community needs not designed by the central government wish. The Fig. 7 is shown the reverse of energy self-sufficient policy driven direction shall be from local community to central government. Moreover, the reflection from 4 seminars shown the essence of a practical strategy of energy autonomous schemas,

by individuals, families, communities, villages, districts, provinces, ministry and government are required in sequence to make everything moving.

The discussions and recommendations from seminars derived the strongly advocate as solutions a combination of government decentralization, devolution to local communities of responsibility for CBNRM held as commons, and community participation (Jagannadha & Janaki, 2006). One of the incorporation of local and community delegates in emerging energy sustainable structures and policy delivery mechanisms is lack of complete understanding of how they operate in discipline, and how best to support and develop effective local energy development. Participation encourages local ownership on energy sustainable community subject to commitment and accountability.

Participation actions develop the agenda information and representation base. It convinces all relevant community stakeholders can be accomplishment:

5.1 The participatory method intends at enhancing utual understanding of stakeholders e.g. community/socialgroups, local and central government officials, private sector organizations, academics and regulators.

5.2 It is not only built a holistic environmental approach and multi-dimensional program ming but also help coordinate information across ecosystems and across sectors.

5.3 It is incorporated knowhow, technologies, experiences, creativities, local resources, including ecological, cultural, socio-political practices and institutions.

When the local community needs are excluded from programming decisions, they will tend to feel confiscate from responsibility for the results. The new direction is shift from government to governance that refers a process of decentralization and involves a transfer of power and roles from national government to ministry of energy, regional, province, district, community, and individual (Yael & et al, 2013).

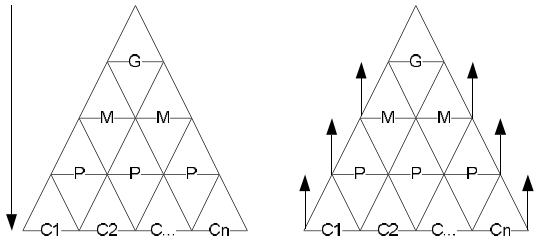

Fig. 7. The reverse of policy driven direction

Participation action approach revealed the varying degrees of community energy autonomy or maturity of actual deployment SCD through CBNRM. The level of mutuality of SCD can be classified into 3 levels as follows, as presented in Fig. 8.

I. Energy negative: Energy systems are ancillary on energy imports and other resources e.g. technologies, capital, material, knowledge, experts etc.

II. Energy Self-Sufficiency: Energy systems are capable of generating and storing enough energy to meet the needs of the entire community with no requirement for energy imports and minimum reliance on outside materials, technologies, expertise etc.

III. Energy positive or absolute autonomy: After past level III, energy systems will be the application of energy autonomy principles and the concept of 100% RE supply while the community still has plenty of energy, materials, or energy products for exporting to beside communities.

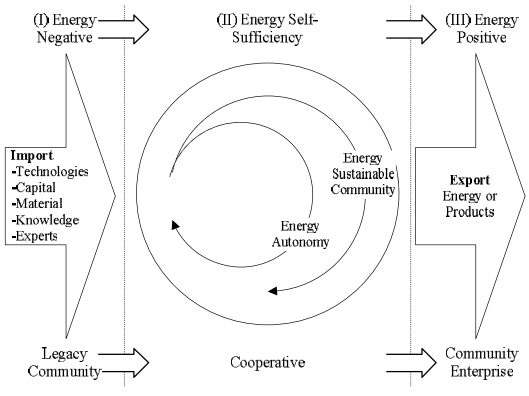

Fig. 8. The degree and scale energy autonomy

After researcher collected all information, recommendations from seminars and passed to Senate Subcommittee meeting, the action model for driven energy sustainable community development (ESCD) were constructed, as illustrated in Fig. 9, as a guide line for presenting for The Senate Standing Committee on Energy. The expectations of this ESCD model are promoting sustainable energy management throughout nationwide communities in Thailand and acting as advisory for Department of Alternative Energy Development and Efficiency: Ministry of Energy on new Renewable Energy ACT.

6. Summary and explanation of results

The governments of developing countries have come under pressure with the effect that their energy policies and strategies highlight the need to shift away from traditional carbon fuels towards renewable energy (RE) e.g. biomass, biogas, biodiesel, solar energy, hydro-power, wind etc. The generation and utilization of renewable energy is predominantly a socio-economic with technical challenge and bioregional motives, this study has shown that the bioregional, social, and political orders of the progressively more important role of renewable energy in sustainable community development (SCD) cannot be ignored. The study results created the supporting action model for driven energy sustainable community development (ESCD) with expectations; the new local policy will support the idea that community demand engagement encourages more favorable local views of community based natural resource management (CBNRM) and it will help a better self -sufficient living under a peaceful community.

7. Discussions

The energy ministry had to study work in new energy resources capable of each local community for electricity generation or other form of energy with an expected potential in local community energy development for the future sustainable energy management such as;

7.1 Thai local communities need intervention from outside community. Since, they are expected the supports will come from central government. However, the government support is not enough to driven community from level I to level II. A lack of knowledge, knowhow, technologies, capital, and mentors is a dead-end of SCD in Thailand. The local administration policy is seen to be a light for SCD. After discuss with Subcommittee Senate on Energy, ESCD on level of provincial governor is the right direction to pursue because we lack of this action level system of governor to support on RE policy.

7.2 Power development plan (PDP) of Thailand has determined by the state policy (Government Center Approach) that secures the government's guidelines. Now, Thailand communities have more complex and sophisticated and they have more concerns and expectations on centralized energy policy. This strategic approach of community energy management needs to be changed from the legacy ways. Communities shall be the one who does formulate policy (Community Center Approach).

8. Recommendations

8.1 Participation action approach helps clarify and stabilize communications and power relationships between Co-management institutions, however, does not necessarily translate into successful practice.

8.2 ESCD enhances iterative of energy sustainable community for national policy direction. While iteration and feedback loops have been part of mainstream of applying RE to ESCD for many years, the idea here is to open for public website or social network ever more to allow for dynamic learning and from co-management institutions to build on experience and learn from mistakes.

8.3 Since, biogas, biomass, and biodiesel are based on energy plants. The promotion on energy crop needs to be reconsidering separated from agriculture production plan. Moreover, it needs more renewable energy act to support on this issue.

9. Acknowledgements

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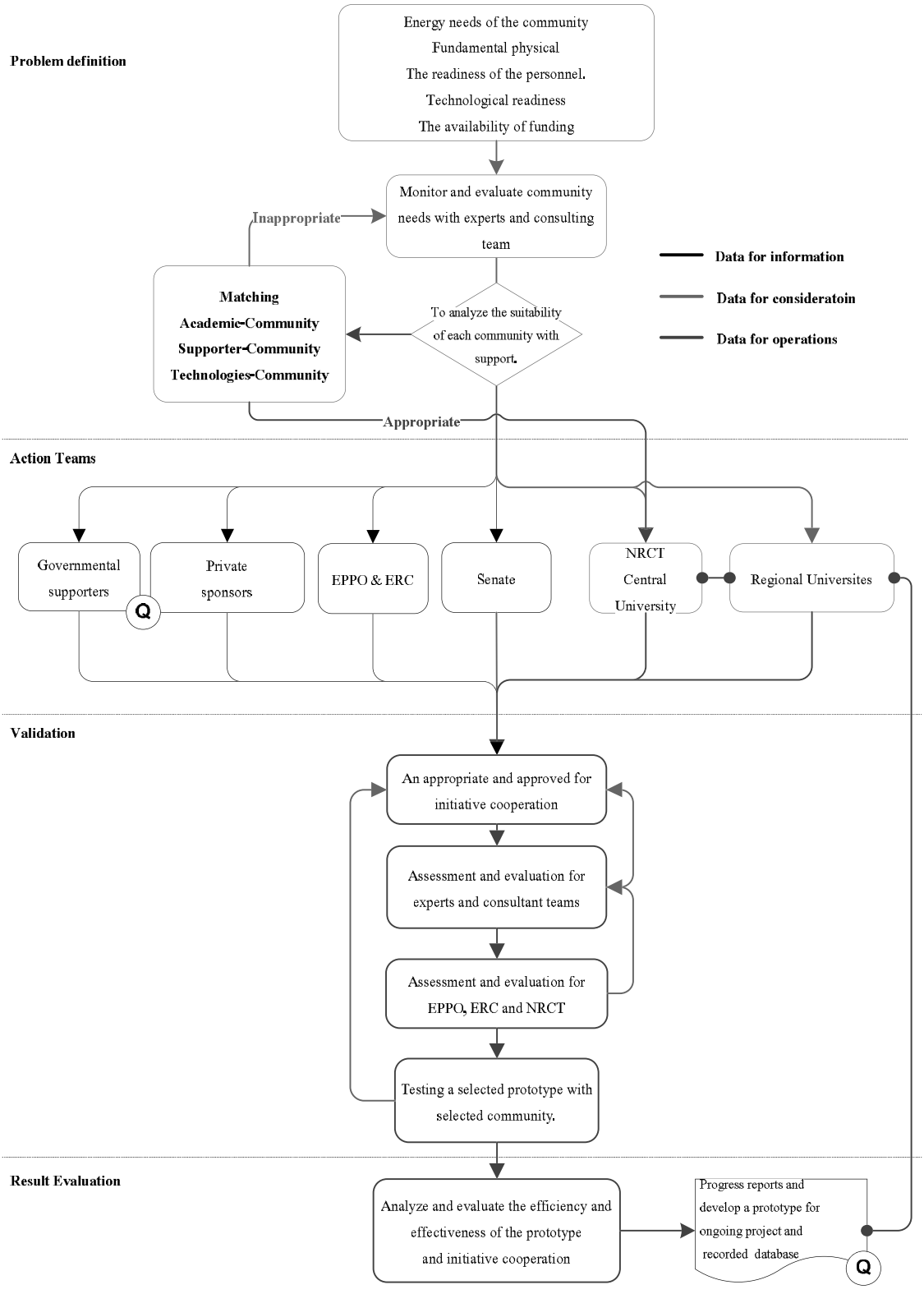

Fig. 9. The action model for driven energy sustainable community development (ESCD)

The Relationship between Mathematical Skills for Business Application and Characteristics of International College Students

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Abstract

This research paper focuses on the relationship between mathematical skills for business applications and the characteristics of international college students. This study used students in KhonKaen University International College as samples and tries to determine the characteristic which may affect the academic performance of students in business/math related courses. The study employed Log-linear multiple regression as a tool to represent this relationship. The significance of each factor was then tested using the Lagrange Multiplier Test (LM test). The results yielded from Covariance Analysis, suggested that the student's ages significantly demonstrate a negative correlations between older students and lower scores. As they aged their scores decreased. On one hand, Sciences/math subject area from high school interacts significantly with both student's age and their English skill – negatively for age and positively for English skill. Moreover, the three nationalities of students – Thai, Chinese, and Vietnamese – interacts significantly with student's ages and moves in the same direction. Lastly, quadratic relationships were expressed on both students' ages and their IQs, implying that as student's ages and IQs increase, their academic performances in business/math related courses increase with increasing rates.

Keywords: Covariance Analysis, LM Test, Mathematical Skills, Student's Characteristics, International College

1. Introduction

KhonKaen University International College (KKUIC) offers many business related courses which require mathematical skills including: Principal of Economics, Business Finance, Accounting for Management, Global Economy and Trade Policies, Business Mathematics and Statistics, and Taxation. Each semester, the total number of students taking those courses is more than 200. Due to differences in the academic backgrounds of students, their performances in business/math related courses tend to vary. In other words, the difference in mathematical skills for business of students should be explained by their various characteristics. Regarding the literatures by many scholars and the researcher's observation, the variables influencing mathematical skills for business application are: student's age (Bull, 2014), IQ (Alloway, 2011), in-class participation (Dommett, 2013), English skill (Pyburn, 2014), prerequisite class taken, subject areas from high school, genders, and nationalities.

Therefore, the research on "The Relationship between Mathematical Skills for Business Application and Characteristics of International College Students" was implemented in order to study various variables – students' characteristics - which may affect mathematical skills for business application of students taking business/math related courses. The model was formulated by log-linear multiple regression, then tested using the Lagrange Multiplier Testing (LM testing), and lastly interpreted the marginal effects of each determinant by Covariance Analysis.

2. Aims

a) To identify the relationship between mathematical skills for business application and characteristics of international college students
b) To analyze the Lagrange Multipliers

3. Theory

Covariance Analysis of Log-linear Multiple Regression Model using Quantitative and Dummy Independent Variables (Ramanathan, 2002):

a) The model is estimated by:
$100\left(\frac{\hat{Y}_1}{\hat{Y}_0}-1\right) = 100\{exp[\hat{\beta}_3 - \frac{1}{2}\widehat{Var}(\hat{\beta}_3)] - 1\}$,
where $\hat{Y}_0$ and $\hat{Y}_1$ are the dependent variables when D_1 (dummy) = 1 and D_0 = 0 respectively; *exp* is exponential function;

and $\widehat{Var}$ is the estimated variance. If the model has an interactive term so that it becomes:

$$ln(Y) = \beta_1 + \beta_2 X + \beta_3 D + \beta_4 DX + u$$

the corresponding expression is much more complicated. Verify that, in this case, it is:

$$100\left(\frac{\hat{Y}_1}{\hat{Y}_0} - 1\right) = 100\{exp[\hat{\beta}_3 - \frac{1}{2}\widehat{Var}(\hat{\beta}_3 + \hat{\beta}_3 X)] - 1\}$$

b) The variance expression depends on the value of X and also involves a linear combination of random variables. As for marginal effects of each determinant, the marginal effect of quantitative variable is $\frac{\delta ln(\hat{Y})}{\delta X} = \hat{\beta}_3 + \hat{\beta}_3 D$. Thus, using logarithmic differentiation property, it becomes:

$$100\frac{\Delta Y}{Y} = 100(\beta_2 + \beta_4 D)\Delta X$$

It follows that $100\hat{\beta}_2$ is the approximate percent of change in Y for a unit of change in X when $D = 0$ and that $100(\hat{\beta}_2 + \hat{\beta}_4)$ is the approximate percent of change in Y for a unit change in X when $D = 1$.

4. Methodology

a) Cross-sectioned data presented below was collected from 107 students from KKUIC who took business-math courses in 2013:

MSKILL = mathematical skills for business application, represented by student's raw scores on business-math courses (e.g. Business Mathematics and Statistics; Business Finance; Global Economy and Trade Policies; and International Political Economy)

AGE = student's ages (Bull, 2014)

IQ = student's IQs measured by IQ scores (Alloway, 2011)

ATTEN = student's attention to classes measured by student's participation scores (Dommett, 2013)

ESKILL = English skill (measured by the average of student's grades on Academic English class and Critical Reading and Writing class) (Pyburn, 2014)

PREREQ = student's number of prerequisite math-related classes taken (researcher's observation)

GEN = student's gender (male = 1 and female = 0) (self-observation)

SC_M = students taking sciences/math subject area from high school (=1, others = 0) (self-observation)

A_M = students taking arts/math subject area from high school (=1, others = 0) (self-observation)

A = students taking pure arts subject area from high school (=1, others = 0) (self-observation)

THA = Thai students (=1, others = 0) (self-observation)

VIET = Vietnamese students (=1, others = 0) (self-observation)

CHI = Chinese students (=1, others = 0) (self-observation)

OTHER = students with other nationalities than THA, VIET, and CHI (=0), used as control group

b) The Lagrange Multiplier Test was used to determine whether some or all stated student characteristics are significant. The following list includes a number of quantitative variables, dummy variables, interactions terms, and squared variables generated through transformations:

0)const 1)MSKILL 2)AGE 3)IQ 4)ATTEN 5)ESKILL 6)PREREQ 7)GEN 8)SC_M 9)A_M 10)A 11)THA 12)VIET 13)CHI 14)OTHER 15)GENxAGE 16)GENxIQ 17)GENxATTEN 18)GENxESKILL 19)GENxPREREQ 20)SC_MxAGE 21)SC_MxIQ 22)SC_MxATTEN 23)SC_MxESKILL 24)SC_MxPREREQ 25)A_MxAGE 26)A_MxIQ 27)A_MxATTEN 28)A_MxESKILL 29)A_MxPREREQ 30)THxAGE 31)THxIQ 32)THxATTEN 33)THxESKILL 34)THxPREREQ 35)VxAGE 36)VxIQ 37)VxATTEN 38)VxESKILL 39)VxPREREQ 40)CxAGE 41)CxIQ 42)CxATTEN 43)CxESKILL 44)CxPREREQ 45)OxAGE 46)OxIQ 47)OxATTEN 48)OxESKILL 49)OxPREREQ 50)sq_AGE 51)sq_IQ 52)sq_ATTEN 53)sq_ESKILL 54)sq_PREREQ

c) Using Gretl software, ln(MSKILL) was regressed against a constant, AGE, IQ, ATTEN, ESKILL, and PREREQ, and then the residuals $\hat{u}_t$ was saved and named uhat1 (Ramanathan, 2002). The following is the auxiliary regression that regresses the residuals against all the variables in the unrestricted model:

Figure 1

Model 2: OLS, using observations 1-107
Dependent variable: uhat1

	Coefficient	Std. Error	t-ratio	p-value	
const	30.2235	15.6263	1.9341	0.05732	*
AGE	-1.44041	0.731539	-1.969	0.05309	*
IQ	-0.0327548	0.193424	-0.1693	0.86604	
ATTEN	-2.2545	2.26967	-0.9933	0.32413	
ESKILL	0.0358782	0.474836	0.0756	0.94	
PREREQ	-0.133772	0.187374	-0.7139	0.47775	
GEN	-5.74171	3.10763	-1.8476	0.06907	*
SC_M	-4.65232	2.48461	-1.8725	0.06551	*
A_M	-5.47474	2.784	-1.9665	0.05338	*
THA	-4.56046	7.98954	-0.5708	0.57004	
VIET	-13.1762	19.899	-0.6622	0.51014	
CHI	-5.54755	6.98792	-0.7939	0.43007	
GENxAGE	0.162422	0.0932886	1.7411	0.08626	*
GENxIQ	-0.0193638	0.0377294	-0.5132	0.60948	
GENxATTEN	0.308841	0.215603	1.4325	0.15666	
GENxESKILL	-0.123716	0.112508	-1.0996	0.27543	
GENxPREREQ	-0.0513443	0.0650067	-0.7898	0.43241	
SC_MxAGE	0.105963	0.0836507	1.2667	0.20964	
SC_MxIQ	0.00170322	0.0371742	0.0458	0.96359	
SC_MxATTEN	0.237241	0.157144	1.5097	0.13582	
SC_MxESKILL	0.127448	0.120828	1.0548	0.29531	
SC_MxPREREQ	-0.0241213	0.068717	-0.351	0.72667	
A_MxAGE	0.0464564	0.0992389	0.4681	0.64121	
A_MxIQ	0.0312891	0.0492229	0.6357	0.52716	
A_MxATTEN	0.471104	0.17502	2.6917	0.00897	***
A_MxESKILL	-0.0439055	0.135549	-0.3239	0.74702	
A_MxPREREQ	-0.0470596	0.0768783	-0.6121	0.54252	
THxAGE	0.251002	0.265314	0.9461	0.34752	
THxIQ	-0.0538028	0.141382	-0.3805	0.70474	
THxATTEN	1.43E-05	0.557737	0	0.99998	
THxESKILL	0.0450185	0.374379	0.1202	0.90465	
THxPREREQ	0.192022	0.137446	1.3971	0.167	
VxAGE	0.51268	0.605755	0.8463	0.40037	
VxIQ	0.311118	0.729132	0.4267	0.67097	
CxAGE	0.304372	0.282076	1.079	0.28444	
sq_AGE	0.0257414	0.0122703	2.0979	0.03969	**
sq_IQ	0.0048721	0.00584979	0.8329	0.40788	
sq_ATTEN	0.103553	0.115139	0.8994	0.37168	
sq_ESKILL	-0.0189182	0.04052	-0.4669	0.6421	
sq_PREREQ	0.00733153	0.0244114	0.3003	0.76485	

Mean dependent var	0	S.D. dependent var	0.23146
Sum squared resid	3.273817	S.E. of regression	0.22105
R-squared	0.423506	Adjusted R-squared	0.087935
F(39, 67)	1.262045	P-value(F)	0.198839
Log-likelihood	34.72124	Akaike criterion	10.55753
Schwarz criterion	117.4707	Hannan-Quinn	53.8987

d) The next step was to select variables to be added to the basic model using simple but arbitrary rule of thumb of including newly added variables that have p-value less than 0.05.
e) Then we regressed selected variables with ln(MSKILL) and omitted variables with insignificant coefficients**,** a few at a time, until all coefficients were significant at 10 percent. (The results are shown in Results section below)
f) Finally, the complete model was estimated with all square and interaction terms.

5. Results

Figure 2

Model 10: OLS, using observations 1-107
Dependent variable: l_MSKILL

	Coefficient	Std. Error	t-ratio	p-value	
const	10.5549	1.748	6.0383	<0.00001	***
AGE	-0.650014	0.170765	-3.8065	0.00025	***
SC_MxAGE	-0.023723	0.0054185	-4.3782	0.00003	***
SC_MxESKIL	0.171011	0.0337917	5.0607	<0.00001	***
THxAGE	0.0289435	0.0108876	2.6584	0.00917	***
VxAGE	0.0370959	0.0122071	3.0389	0.00304	***
CxAGE	0.0281024	0.0113152	2.4836	0.0147	**
sq_AGE	0.0146108	0.00384282	3.8021	0.00025	***
sq_IQ	0.001757	0.00071479	2.4581	0.01572	**
Mean dependent var	4.135463		**S.D. dependent var**	0.261524	
Sum squared resid	4.3389		**S.E. of regression**	0.210415	
R-squared	0.401516		**Adjusted R-squared**	0.352661	
F(8, 98)	8.218396		**P-value(F)**	1.86E-08	
Log-likelihood	19.65221		**Akaike criterion**	-21.3044	
Schwarz criterion	2.751048		**Hannan-Quinn**	-11.5527	

Figure 2 indicates the results of Lagrange Multiplier Test on all the suspected characteristics (variables) of business/math students in KKUIC. The value R-squared statistic of 0.40 is quite acceptable for cross-sectioned data with the corresponding p-value(F) of 1.86E-08. Additionally, p-values of all the selected variables (AGE, SC_MxAGE, SC_MxESKILL, THxAGE, VxAGE, CxAGE, sp_AGE, sq_IQ) demonstrate that all coefficients in the model are significant at 10 percent or lower level. As a result, the logarithm of MSKILL is well explained by the constructed model, and hence, clearly signifying the superiority of this model. Moreover, the results neglect some variables namely ATTEN, PREREQ, GEN, A, and OTHER, suggesting that they are insignificant.

6. Summary and Interpretation of Results

To analyze the impact of each variable on MSKILL in-depth, the marginal effects of each determinant was examined separately:

Age: Student's age is essential in explaining student's mathematical skills for business application. It exhibits significant nonlinearity and it also interacts significantly with sciences/math subject area and student's nationalities (Thai, Vietnamese, and Chinese). The partial effect is:

$$\frac{\Delta \ln \widehat{(MSKILL)}}{\Delta AGE} = -0.65 + 0.29AGE - 0.024SC\_M + 0.029TH + 0.037V + 0.028C$$

According to the above derivative, the additional raw score on business-math courses for one additional year of age increases with an increasing rate as students get older. Interestingly, one year older in age indicates 2.4 percent decrease in student's scores on business/math courses for students from sciences/math high school subject area. This is because the majority of students taking business-math related courses are from sciences/math subject area in high school. As their ages increase, students are moving towards the upper division courses with increasingly higher degree of difficulty, resulting in lower scores. In addition, student's nationalities interact significantly with their ages. On average, one year older in age means 2.9 percent increase in scores for Thai students, 3.7 percent increase in scores for Vietnamese students, and 2.8 percent increase in scores for Chinese students.

English Skill: English skill of students significantly interact with students who took science/math subject area from high school level. The partial effect is:

$$\frac{\Delta \ln \widehat{(MSKILL)}}{\Delta ESKILL} = 0.17SC\_M$$

Regarding the above derivative, as the average of student's grades on Academic English class and Critical Reading and Writing class increase by one point, students from science and math subject area can score 17 percent more.

IQ: Student's IQ represents nonlinear relationship with student's mathematical skills for business application. The partial effect is:

$$\frac{\Delta \ln(\widehat{MSKILL})}{\Delta IQ} = 0.0035IQ$$

As IQ scores increase by one point, student's additional raw score in business-math courses increases by 0.35 percent along with IQ. In other words, as student's IQ rises by one point, student's mathematical skills for business application will increase with an increasing rate.

Nationalities: The sample of students belonged to 4 different nationalities: Thai, Vietnamese, Chinese, and others, where other nationalities are used as the control group. The estimated partial effects for log MSKILL for each of the non-control group are:

Thai: $0.029AGE$

Vietnamese: $0.037AGE$

Chinese: $0.028AGE$

As pointed out earlier, age significantly has a positive effect on Thai, Vietnamese, and Chinese students but not for students with other nationalities.

Sciences/Math Subject Area: The partial effect for log MSKILL is:

$$\frac{\Delta \ln(\widehat{MSKILL})}{\Delta SC\_M} = -0.24AGE + 0.17ESKILL$$

As indicated earlier, students with science/math subject area from high school have the raw scores in business-math courses that negatively interact with age but positively interact with English skill.

7. Recommendations

Recommendations from the analysis of the Lagrange Multiplier can be categorized into three main groups:

a) In order to effectively select new students, younger students who have completed sciences/math subjects are more preferable. This is because sciences/math are the only subject areas which seem to effect students academic performances on business/math related courses. Moreover, Thai, Chinese, and Vietnamese nationalities were selected for business/math courses because the model significantly demonstrated positive impacts of these nationalities on student's business/math academic performances. Additionally, a student's IQ also resulted in a somewhat positive relationship with their business/math proficiency. Thus, it is recommended that an IQ test be included in the admission process.

b) For effective teaching strategy and student's learning success, it is recommended that students from sciences/math subject areas in high school take English courses (either provided by KKUIC or outside institution) along with their regular courses. This is because the model indicates that English skill have the highest value of coefficient (17 percent) compared with other variables and move in the same direction as the academic performance of students. Further taking its p-value into account (<0.0001), English skill becomes the most important factor leading students to do well in business/math courses taught in English.

c) As for possible future studies, in order to increase the value of R^2 (the goodness of fit) which may result in a greater accuracy of the model, changes in statistical model and the addition of new variables is strongly recommended.

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