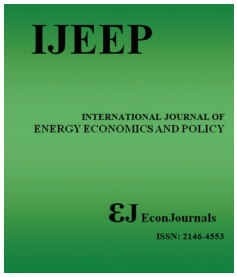

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Exploring the Relationship between Fossil Fuel Energy Consumption, Renewable Energy Consumption and Human Capital Index: A Study From Thailand

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ABSTRACT

This study examines the trend in human capital index (HCI) in the economy of Thailand during 1990-2010 while considering the fossil fuel and renewable energy consumption as main independent variables. However, some macroeconomic variables like expenditure side real GDP, output side real GDP, population, number of persons engaged/ employed, are average annual hour of working are added as controls. Overall three empirical findings are provided considering the separate and combine effect of fossil fuel, energy consumption from renewable sources on HCI along with control variables. Findings show that fossil fuel is negatively while renewable energy is positively impacting on human capital index in Thailand over last two decade. Study findings have provided some sensible and rationale contributions in the literature of environmental sustainability and community as well. However, limitations are also attached to this study. First, time duration of the study has only observed the horizon until 2010 while ignoring the recent decade. Second, human capital index is only observed through educational measure. Third, time series trend like short run and long run are neglected. Fourth, carbon emission in the natural environment was also not included in the model, yet it might be a significant determinant of HCI. Besides, practical implication of the study justify for the support of various stakeholders.

Keywords: Human Capital Index, Renewable Energy Consumption, Fossil Fuel Consumption, Thailand
JEL Classifications: K32, E24

1. INTRODUCTION

For economic and social development of a country, energy is considered as a key pillar (Campling and Rosalie, 2006; Murphy, 2012; Nurse, 2006; Wang et al., 2018). The reason is that it is playing a role as core factor of social wellbeing. However, one of the growing concern in the literature specifies the focus on renewable sources of the energy which can ultimately provide some positive outcome for overall climate change in the world (Edenhofer et al., 2011; Owusu and Asumadu-Sarkodie, 2016; Şen, 2008; Sims, 2004; Kanwal et al., 2020; Khan et al., 2020; Hornung, 2020). Both sustainable development and overall production output in any economy are widely depending on the range of energy sources (Omer, 2008; King and Samaniego, 2020; Malayer Rodriguez and Vargar Perez, 2020). Not only for the recent development and growth but also for the Millennium development targets, energy sources are vital in their significance. The emerging topic in the field of economics and sustainability specifies the importance of energy on economic growth with the human well-being too. A lot of social and community based facilities are depending on the provision of energy from different sources (Choi and Kim, 2014; Daw et al., 2012; Makino et al., 2015). These facilities include health, education, communication, and transportation, etc. Provision of electricity for the community shows a trend of good basic necessity as provided by the government and related department. However, contrary to this, lack of energy-related facilities displays the poor infrastructure with adverse effect on daily life, health, and education, etc. For the social development, overall energy consumption can be used as a

reasonable determinant (Akizu-Gardoki et al., 2018; Martinez and Ebenhack, 2008; Shahbaz et al., 2019; Tugcu et al., 2012; Wang, 2014; 1. Abadía Alvarado and De la Rica, 2020; Bibi, 2020; Burgos and Bocco, 2020).

Like many other sources of the energy, two are under significant consideration; fossil fuel energy consumption and renewable energy consumption. The term fossil fuel has been accepted as fundamental energy production system or the source both in developed and emerging economies (Hall and Scrase, 1998; Talinli et al., 2010; Yan and Hino, 2016). However, countless studies have shown their reservations regarding the usage of fossil fuel energy. One of the most critical problem to climate is air pollution along with global warming as pragmatic with the consumption of fossil fuel energy (Jacobson, 2010; Kamran and Omran, 2018; Mukhopadhyay and Forssell, 2005). Conversely, some studies have argued the adverse economic results of fossil fuel energy from different sources (Cleveland et al., 1984; Gambhir et al., 2014; Machol and Rizk, 2013; Tugcu et al., 2012). Due to such issues, it is an ongoing phenomenon to achieve a sustainable energy system which can provide a range of benefits to different stakeholders. For the calculation and measurement of fossil fuel energy consumption, key factors like solid fuel, total petroleum products, Gas, and ross inland energy consumption may be observed (Martins et al., 2018). However, the first three sources of energy will be added together and fourth will be worked as a dominator to provide a final value of Fossil fuel energy consumption (Martins et al., 2018).

On the other hand, renewable energy consumption specifies the focus on creating the awareness about the environmental issues and related threats (Kamoun et al., 2019). Although a common notion is that energy sources are highly linked to environmental outcomes, yet the focus on renewable sources would provide some good economic results. In this way, some of the topics which are examined with the renewable energy consumptions are: economic growth, employment, local sustainability, income distribution, financial development and so on (Kamoun et al., 2019; Sharif et al., 2019; Geng, 2020; Goo et al., 2020; Ariantjelangi, 2020; Gautam et al., 2020). However, a latest topic in the field of energy economics provides the empirical relationship between the renewable energy consumption and income inequality. Meanwhile, it is observed that lot of the economies in the world has developed/adopted the policies to promote renewable energy technologies.

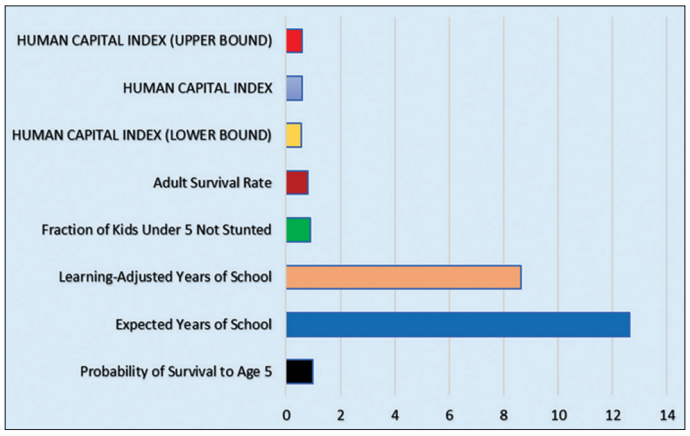
Human capital index is a budding subject in the field of social development which states the capability of the countries to potentially mobilize and utilize the economic and professional capabilities of their citizens. During 2018, HCI was published for the very first time and considered 157 countries worldwide. The overall range of HCI covers 0-1, where 0 indicates no potential of the citizens in terms of economic and professional capabilities was utilized while 1 shows the highest potential is achieved. In ASEAN region, different economies have observed a diversified score, hence presented a good potential of HCI. For example, a latest findings for HCI world ranking shows that with the highest score of 0.88, Singapore is on the top of the rank. However, Thailand has attained a total score of 0.60 with the global ranking of 65. To the best of the author finding with the critical review of the literature, a profound gap is found to explore the impact of fossil fuel energy consumption, and renewable energy consumption on HCI in Thailand. Figure 1 shows the various indicators of HCI and their scoring trend during 2018.

2. LITERATURE REVIEW

Research studies have provided the empirical answer to the question whether the energy sources like fossil fuel consumption and renewable consumption have their any link with the human capital and macroeconomic dynamics. For instance, Yao et al. (2019) have examined the relationship between human capital with the energy consumption pattern in OECD during a time of 1965 to 2014. Their preferred results show that there is cross sectional dependency structural breaks in the variables, showing that one standard deviation change in the human capital causing a reduction of 15.36% in overall consumption of energy in selected region. However, the factor of human capital generates significantly externalities for the natural environment. Rafindadi and Mika'Ilu (2019) analyze the sustainable energy consumption and its influence on the sustaniblity of the United Kingdom (UK) while taking the capital formation and economic growth under their observations. The data period of their study was from 1970 to 2013 with yearly observation while applying the ARDL bound testing and cointegration test. Their findings confirm the presence of cointegration about the selected variables of the study. At the same time, steady economic growth is found to be a significant determinant of energy consumption in the country.

Wang et al. (2018) explain their view that major energy consumption in the global economy is primarily the result of human activities. However, one of key question to answer is how renewable energy consumption can influence on the overall human development, which needs to be more explored in recent time. Therefore, they have explored the relationship between renewable energy consumption, and human development index with the economic growth in the economy of Pakistan during 1990-2014. Their empirical findings say that there is no evidence for the contribution of renewable energy consumption in the development of human capital in Pakistan. Contrary to earlier results, it is observed that higher the income in the country lower the human development and vice versa. Addition to this, more carbon emission like CO_2 means more the human development index.

Figure 1: HCI trends in Thailand



Source: World Economic Forum , 2018

Salim et al. (2017) investigate the dynamic association between human capital and energy consumption for the data of China during 1990-2010. Notice the issue of cross sectional dependency, and heterogeneity for the space and time, there study confirms the negative and significant relationship between human capital and energy consumption in Chinese economy. More specifically, their study justifies that 1% increase in the human capital can cause a reduction in energy consumption within a range of 0.18-0.45%. Their findings highly suggest that for the more energy conservation, there is a significant need to focus for the improvement of human capital components like training on the job and learning by doing factors respectively.

Fang and Chen (2017) have studied the growth-energy nexus both aggregate and disaggregate level in Chinese economy. For addressing the study objectives, human capital and production function of energy augmentation was also used. Their findings show that the factor of human capital is applying almost 2-3 times the influence of physical capital on the overall economy of China. Meanwhile, the role of energy is also very significant, hence should be considered in the policy review process. Shahbaz et al. (2019) have investigated the effect of education and diversification of the export in determining the energy demand for the US economy. For this purpose, authors have applied the unit root test, and ARDL methodology to review the structural breaks in the data sets. Their empirical findings have confirmed that there is long run but cointegrated association between the variables. Whereas energy factor is negatively impacting on the education. As per the detailed investigation, a theoretical and empirical gap is found for the economy of Thailand, considering the energy sources and their influence on the human capital. Therefore, this study is carried out to explore the relationship between fossil fuel consumption, renewable energy consumption on HCI with the controlling effect of macroeconomic dynamics.

3. VARIABLES AND RESEARCH METHODOLOGY

Table 1 delivers the material about the dependent (HCI), independent (FFOCNS, RECONS), and control variables (RGDPE, RGDPO, POP, EMP, and AVH), covering their official definition and measurement.

Equation I-III provides the understanding for the relationship between human capital index as main dependent variable, fossil fuel consumption and renewable energy consumption as main independent variables, and control variables with the title of expenditure side real gross domestic product, output side real gross domestic product, population level, employment, and average annual work force. As explained in the previous section this study is observing the trends for both independent and dependent variable over the time series of 1990-2010, therefore, it is known as quantitative research with secondary data from two different sources; World Development Indicators WDI, and Penn world data base. Both of these sources are widely accepted, hence no issue for the data reliability and its credibility. Under equation-1, only the effect of fossil fuel consumption for HCI with the macroeconomic dynamics as control variables is empirically tested. Equation-II investigates the influence of renewable energy consumption as main independent variable along with macroeconomic control variables. Whereas, Equation-III specifies the combine effect from both the energy sources as independent variable 1 and independent variable 2 respectively. Besides, *f0-f7* are showing the regression parameters both constant and coefficients respectively. Whereas U denotes the error terms of all the models.

$$HCI = f0 + f1(Fossil\_Fuel\_Consumption) + f2(Expenditure\_Side\_RealGDP) + f3(Output\_Side\_RealGDP) + f4(Population) + f5(Employment) + f6(Average\_annual\_Work) + U \quad (1)$$

$$HCI = f0 + f1(RenewableE\_Consumption) + f2(Expenditure\_Side\_RealGDP) + f3(Output\_Side\_RealGDP) + f4(Population) + f5(Employment) + f6(Average\_annual\_Work) + U \quad (2)$$

Table 1: Variable and their official definitions

Title and Abbreviation	Official Definition
Human capital index (HCI)	HCI indicates the ability of a country for mobilizing the economic and professional potential of their citizen. It is measured through based on years of schooling and returns to education as presented by PWT9
Fossil fuel consumption (FFCONS)	Fossil fuel comprises the elements like coal, oil, petroleum, and natural gas products. It is measured through % of total fuel consumption in any economy as expressed by World Development Indicator
Renewable Energy Consumption (RECONS)	Renewable energy consumption is the share of renewable energy in total final energy consumption. It considers the energy from renewable sources like wind, rain, sunlight, and geothermal heat, etc.
Real Gross Domestic Product (GDP); expenditure side (RGDPE)	RGDPE shows expenditure-based real GDP measured in Million US Dollars. It helps to conduct a relative comparison for the living standards of the countries
Real Gross Domestic Product (GDP): Output-side (RGDPO)	RGDPO shows the output-based real GDP, measured in Million US Dollars. It helps to analyze the productive capacity over the time and across the countries
Population: POP	POP shows total individuals in a country as measured by the WDI
Employment: EMP	EMP includes all the individuals in a country who are at the age of 15 or above and performing a specific work, measured in number of persons engaged
Average annual hours worked: AVH	Average annual hours worked by persons engaged

$$HCI = f0 + f1(Fossil\_Fuel\_Consumption) + f2(RenewableE\_Consumption) + f3(Expenditure\_Side\_RealGDP) + f4(Output\_Side\_RealGDP) + f5(Population) + f6(Employment) + f7(Average\_annual\_Work) + U \quad (3)$$

4. RESULTS AND DISCUSSION

This study has provided both descriptive and regression results. Initially, variables like fossil fuel consumption, and renewable energy consumption as entitled as main dependent variables, whereas, human capital index is known as main independent variable. Addition to this, some macroeconomic dynamics were also observed in the study results as control variables. For dependent variable, trends in mean score are 77.32 and 23.31 with dispersion of 5.68 and 4.25 accordingly. It denotes FFCONS is presented higher mean and higher standard deviation, relatively to RECONS. Similarly, the trends in terms of minimum and maximum observations of FFCONS is found to be higher than RECONS which are 63.83 and 82.05. The mean trend for Human Capital Index abbreviated as HCI is 2.269 as measured through based on the schooling and return to the education. Whereas standard deviation for HCI is very low when compared with other variables of the study. As per the control variables, the trends in mean score and other descriptive findings are presented in Table 2. For better understanding of the variables, Figure 2 provides the historical trend during 1990 to 2010 for Fossil Fuel Consumption which shows an increasing trend, hence causing more carbon emission in the natural environment. Meanwhile, Figure 3 demonstrates that for the renewable energy consumption, there was Peak consumption during 1990-1995 with the decreasing trend, which comes into a huge decline during 2000-2005. However, after the year of 2005 there is a gradual increase but not as per the earlier years like the one during 1990-1995. For providing the reader with the good view of HCI, Figure 4 shows the HCI score during the study period while Figure 5 shows the overall descriptive looks on all the variables. It is crystal clear that HCI trends has a significant growth over the last 2 decades and by the end of 2010 it observes a highest score.

As observed through regression model 1, Table 3 shows the effect of fossil fuel consumption on HCI in Thailand over 1990-2010. As observed that with the controlling influence of all macro-economic variables, impact on FFCONS on HCI is −0.285. This effect justifies that over the last 2 decades during 1990 to 2010, although there is an increasing trend in HCI, however, the influence from FFCONS shows an adverse impact. It explains that higher the fossil fuel consumption, lower the HCI in Thailand which needs to be examined on serious grounds. Furthermore, expressing the effect of control variables on HCI, significant but positive indication is found from REGDPE, RGDPO, while POP has shown significant but negative impact as shown in Table 3. An overall R2 is 89.7 showing a good variation in HCI as observed through Fossil fuel consumption and control variables of the model. While, overall model is highly significant at F-test is showing a good score above the threshold point, meaning that regression parameters are statistically different than zero. Equation IV shows the regression coefficients with each of the variable titles.

Figure 2: Trends in Fossil Fuel Consumption 1990-2010

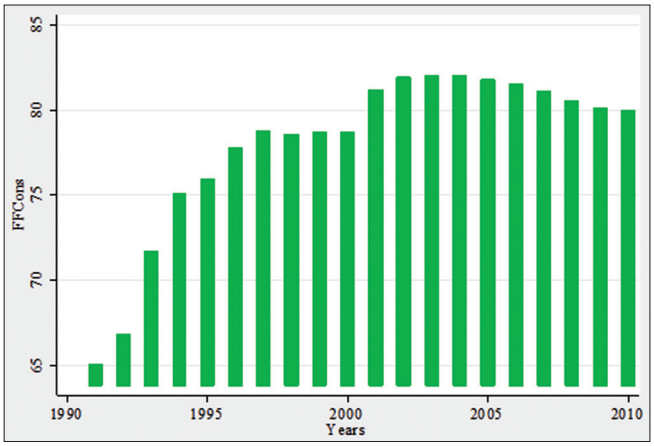


Figure 3: Trends in Renewable Energy Consumption 1990-2010

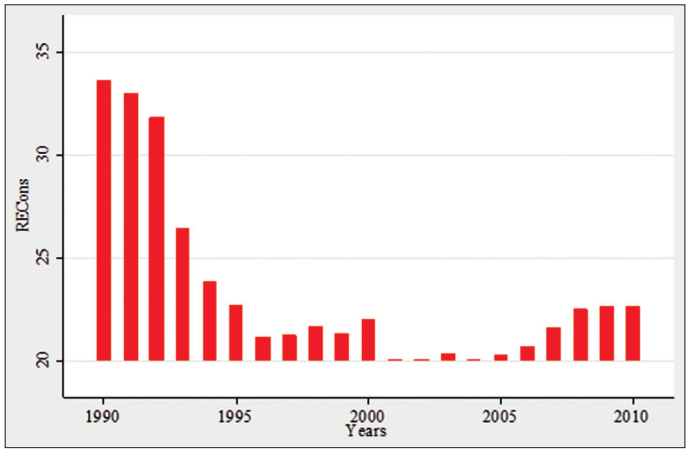


Table 2: Descriptive statistics

Variables	Obs.	Mean	SD	Min	Max	p1	p99	Skew.	Kurt.
FFCONS	21	77.322	5.682	63.838	82.057	63.838	82.057	−1.378	1.588
RECONS	21	23.317	4.258	20.025	33.639	20.025	33.639	1.619	1.179
HCI	21	2.269	0.158	2.045	2.553	2.045	2.553	0.301	1.863
Control variables of the study									
RGDPE	21	531000	161000	284000	874000	284000	874000	0.527	2.438
RGDPO	21	519000	149000	302000	834000	302000	834000	0.556	2.309
POP	21	62.381	3.514	56.583	66.692	56.583	66.692	−0.208	1.572
EMP	21	33.49	2.961	29.894	38.641	29.894	38.641	0.514	1.718
AVH	21	2271.969	34.565	2197.231	2316.345	2197.231	2316.345	-1.341	3.754

Table 3: Impact of FFC on HCI with the presence of economic dynamics

HCI	Coef.	SE	t-value	P-value	Sig.
FFCONS	−0.285	0.030	−9.50	0.000	***
Control variables of the study					
RGDPE	0.125	0.140	4.08	0.000	***
RGDPO	0.572	0.098	5.83	0.000	***
POP	−0.030	0.00	−7.50	0.000	***
EMP	0.003	0.003	1.11	0.285	
AVH	0.142	0.124	1.14	0.157	
_cons	0.417	0.621	0.67	0.513	
Mean dependent var	2.269	SD dependent var		0.158	
R-squared	0.897	Number of obs.		21.000	
F-test	127.784	Prob > F		0.000	
Akaike crit. (AIC)	−130.029	Bayesian crit. (BIC)		−122.718	

Indicates that ***P<0.01, **P<0.05, *P<0.1 respectively.

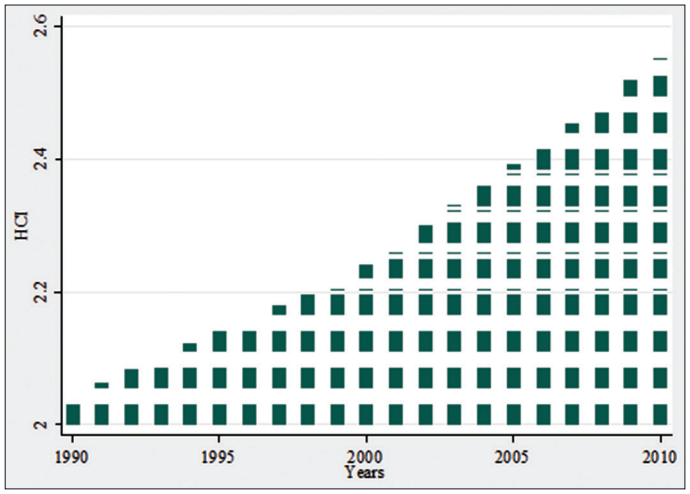
$$HCI = f0:0.417 + f1(Fossil\_Fuel\_Consumption : -0.285***) + f2(Expenditure\_Side\_RealGDP : 0.125***) + f3(Output\_Side\_RealGDP : 0.572***) + f4(Population : -0.030****) + f5(Employment : 0.003) + f6(Average\_annual\_Work : 0.142) + U \quad (4)$$

With the controlling effect from economic dynamics, Table 4 shows the influence of renewable energy consumption (RECONS) on HCI as observed through regression equation II. Considering the fact that higher consumption of energy from some new sources more HCI will experienced; coefficient is 0.005 and standard error of 0.002 have provided a t-value of 1.87, hence p-value of 0.082 significant at 10%. This effect would consider the assumption that economy of Thailand has an increasing trend in HCI which is a positive outcome of RECONS during 1990-2010. This fact has provided a good evidence for the analysts in the field of energy economics and similar fields who are involved in making strategic decisions with the guidelines. In examining the effect from control variables, positive impact is found from RGDPE, RGDPO, and POP factors. This result would justify the fact that some of the economic indicators have their direct influence while others are found to be insignificant indicators of HCI. For indicating the model fitness, F-test and aggregate variation in HCI is 117.92, and 71.7%. Equation IV is showing the regression coefficients with the constant value of HCI.

$$HCI = f0:0.145 + f1(Renewable.E\_Consumption : 0.005*) + f2(Expenditure\_Side\_RealGDP : 0.874***) + f3(Output\_Side\_RealGDP : 0.028**) + f4(Population : 0.003****) + f5(Employment : 0.014) + f6(Average\_annual\_Work : 0.917) + U \quad (5)$$

By the end, this empirical study has evaluated whether the effect of RECONS and FFCONS is significant when observed under one regression model with the presence of economic dynamics as control variables. As per the observed findings, RECONS is showing a regression parameter of 0.573. This would explain that higher consumption of renewable energy, increasing score of

Figure 4: Trends in HCI: 1990-2010



HCI was experienced in Thailand. This effect is also shown under Table 5 and regression equation VI, with the significant t-value of 8.18 respectively. For FFCONS, a highly significant but negative impact on HCI is found, saying that fossil fuel consumption is causing a decline in human capital index. The statistical evidence to accept this effect of FFCONS on HCI is found as t-value is above the threshold level of 1.96, hence significant level is 1%. This is observed that when the fossil fuel consumption and renewable energy consumption are combined under one model with the controlling effect of economic dynamics, mixed impact on HCI is found. Through economic dynamics significant and positive influence from REGDPE, RGDPO, and POP is once again proved. Besides, overall model is explaining a coefficient of determination with the score of 89.7%, hence a higher variation in HCI. Equation VI shows the regression parameters for better understanding.

$$HCI = f0:0.145 + f1(Renewable.E\_Consumption : 0.573***) + f2(Fossil\_Fuel\_Consumption : -0.672***) + f3(Expenditure\_Side\_RealGDP : 0.369***) + f4(Output\_Side\_RealGDP : 0.632**) + f5(Population : 0.029****) + f6(Employment : 0.003) + f7(Average\_annual\_Work : 0.182) + U \quad (6)$$

Figure 5: Overall descriptive look of the variables

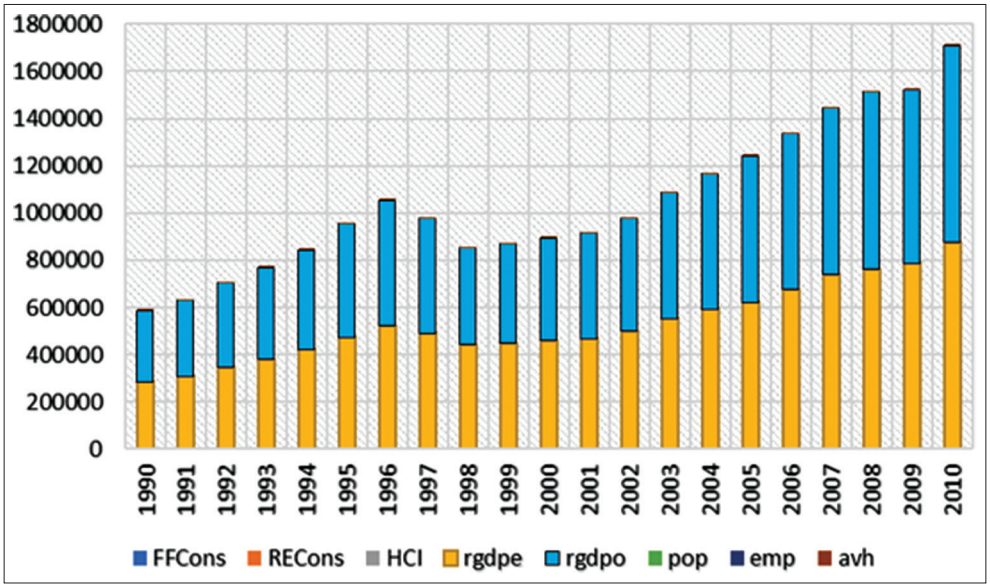


Table 4: Linear regression impact of RECONs on HCI with the presence of economic dynamics

HCI	Coef.	SE	t-value	P-value	Sig.
RECONS	0.005	0.002	1.87	0.082	*
Control variables of the study					
RGDPE	0.018	0.002	9.04	0.000	***
RGDPO	0.874	0.118	7.406	0.000	**
POP	0.028	0.003	10.81	0.000	***
EMP	0.014	0.063	0.95	0.357	
AVH	0.917	0.524	1.75	0.988	
_cons	0.145	0.719	0.20	0.843	
Mean dependent var	2.269	SD dependent var		0.158	
R-squared	0.717	Number of obs.		21.000	
F-test	117.292	Prob > F		0.000	
Akaike crit. (AIC)	−130.110	Bayesian crit. (BIC)		−122.798	

Indicates that ***P<0.01, **P<0.05, *P<0.1 respectively

Table 5: Linear regression Impact of RECONS and FFCONS on HCI with the presence of economic dynamics

HCI	Coef.	SE	t-value	P-value	Sig.
RECONS	0.573	0.070	8.18	0.000	***
FFCONS	−0.672	0.027	−24.88	0.000	***
Control variables of the study					
RGDPE	0.369	0.081	4.55	0.000	***
RGDPO	0.632	0.064	9.87	0.000	***
POP	0.029	0.004	6.77	0.000	***
EMP	0.003	0.003	0.91	0.380	
AVH	0.182	0.107	1.70	0.124	
_cons	0.235	0.802	0.29	0.774	
Mean dependent var	2.269	SD dependent var.		0.158	
R-squared	0.897	Number of obs.		21.000	
F-test	48.937	Prob > F		0.000	
Akaike crit. (AIC)	−128.234	Bayesian crit. (BIC)		−119.878	

Indicates that *** p<0.01, ** p<0.05, * p<0.1 respectively.

5. CONCLUSION

In present research, reserachers have investigated the effect of fossil fuel consumption, renewable energy consumption along with macroeconomic control variables on human capital index of Thailand during the time of 1990-2010. The overall research findings are divided into three major discussion. Under first regression results, the impact of only fossil fuel consumption on HCI was tested, while controlling for all the macroeconomic variables as added and presented in this study. It is found that while controlling for the macroeconomic dynamics, significant and negative impact of fossil fuel consumption on HCI is found which predicts the reduction in human index overall score. However, this effect is only justified when the model is controlled for the regional

economic indicators. Under second discussion, renewable energy consumption is observed as independent variable along with the same control variables. Findings are providing the evidence for more HCI as more usage of energy from renewable sources is tested in Thailand. This fact is also indicating the significant impact of control variables like RGDPE, RGDPO and POP accordingly, whereas remaining are found to be insignificant determinant of HCI for Thailand economy. The third discussion of the study justify the highly significant and positive impact of renewable energy consumption, but highly significant and negative impact of fossil fuel consumption on HCI, adding the same control variables.

In terms of policy implication, It is widely assumed that for analyzing the trends in HCI, both fossil fuel and renewable energy consumptions should deeply be observed. For policy makers and research experts in energy economics, this study could be of great support through justifying its significance with empirical findings. It is highly suggested that fossil fuel and energy consumption from renewable sources are two major determinants so they should be observed accordingly. More specifically, dealing with the changing climate issue, researchers should also consider the social outcomes of environmental factors. However, for the future research studies, it is widely believed that limitations of the present study can be evocative guidance for different stakeholders. First, time duration of the study has only observed the horizon until 2010 while ignoring the recent decade. Second, human capital index is only observed through educational measure. Third, time series trend like short run and long run are neglected. Fourth, carbon emission in the natural environment was also not included in the model, yet it might be a significant determinant of HCI. Hence, future studies may address all stated limitations for better contribution in the literature of sustainable environment and community too.

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