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ENERGY CONSUMPTION AND ECONOMIC GROWTH NEXUS: A COMPARATIVE ANALYSIS OF US, CHINA AND JAPAN

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ABSTRACT

This study has chosen top three economies of the world to explore the relationship between energy consumption and economic growth by using annual data from 1985-2020. The results of ARDL approach shows that energy has a positive and significant impact on the economic growth of USA, China and Japan. Japan is the largest beneficiary in the short run as well in the long run, followed by USA and China.

Key Words: *Economic Growth, Gross Capital Formation, CPI, Real Exchange Rate*

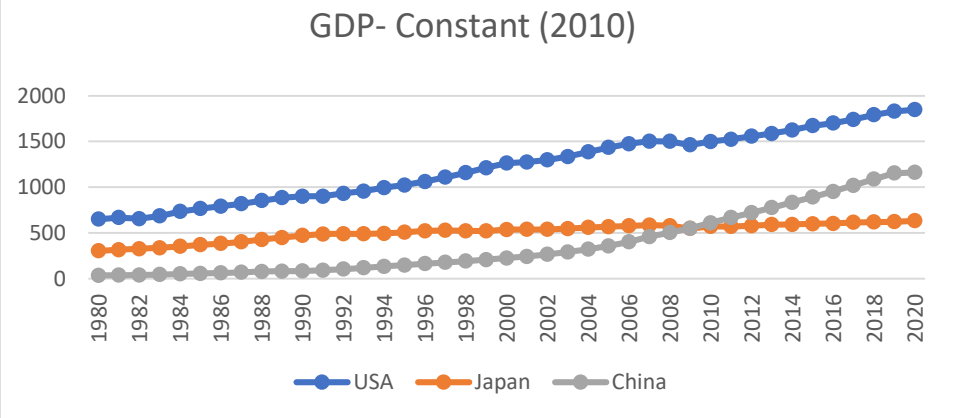
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1. BACKGROUND OF THE STUDY

Economic growth is essential for improving the standard of living in a society as it increases the rate of consumption of goods and services by minimizing poverty. It is also a reflection of the state of the innovative ability of a nation and how effectively the society takes limited resources and makes better use of them. GDP growth is important for consumption, creation of jobs, education, health, investment, public services and it gives a greater choice of lifestyles leading to a virtuous cycle of economic prosperity and happiness. Nations can achieve economic growth in different ways and this study emphasizes the role of energy in this regard. It is hypothesized that the effect of energy and other explanatory variables may be different for different countries even if they are in same category of development like even if they are in the developed countries list. This study took top three economies of the world; USA, China and Japan and studied the impact of energy on their economic growth.

The impact of energy is studied by various scholars like Bhattacharya et al. (2016), Jebli et al. (2016), Alper and Oguz (2016), Kahia et al. (2017), Rafindadi and Ozturk (2017), Gozgor et al. (2018), Ji and Zhang (2019), Alam and Murad (2020), Sharif et al. (2020), Zeren and Akkuş (2020), Awodumi and Adewuyi (2020) and mostly shows the positive impact of energy on the economic growth. Different proxies can be used for energy consumption and in this study energy consumption per capita is used as a proxy of energy and interestingly these top three economies of the world are also top consumers of the energy when energy is measured as energy consumption per unit (the world Bank 2020) although the order is slightly different. USA is the top economy (GDP) and also top consumer of the energy where as China is the second largest economy but fourth top consumer and Japan is the third largest economy but the second largest consumer of the energy. All this is shown in the figure (1) and figure (2).

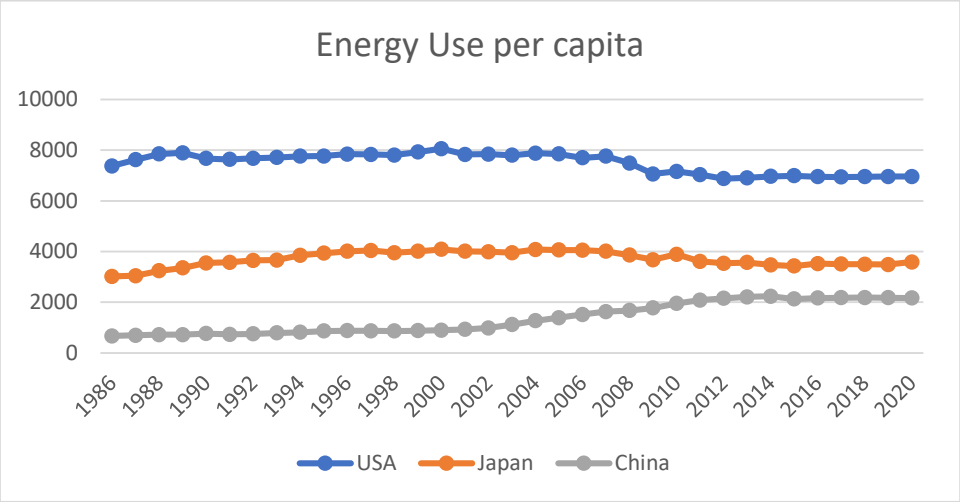
Figure 1: Trends of GDP 1980-2010



Source: The World Bank, Graph by Authors

USA is the top economy throughout of the period where as Japan was second till 2009 and then China over took it and become the second largest economy and Japan shifted to the third slot. Values given in the figure are GDP at constant price and GDP amount in current price is different and higher in all these three countries.

Figure 2: Use of Energy Per Capita



Source: The World Bank, Graph by Authors

Figure (2) indicates that USA is top energy consumer (in term of energy consumption per capita) since the period of study 1980 while the position of Jan remains seconds throughout the period where as China has lower energy consumption through the period as compared to these countries. The objective of this study is to find the impacts of energy consumption on the economic growth in case of Japan, China, and USA by using annual data from 1985-2020.

2. REVIEW OF LITERATURE

2.1 Energy and Economic Growth

Dai et al. (2016) examined a possible scenario of energy development in china towards 2050 and concluded that the impact of this will be direct production of renewable energy products that will be 3.4 % of gross domestic product and to make comparison they told that the share of agriculture accounted for (2.5%), construction (2.1%) and iron and steel (3.3%). They used dynamic computable general equilibrium (CGE) model with two scenarios: a reference scenario assuming conventional development of renewable energy

and a renewable energy max scenario. In case of renewable energy max scenario, it would cause a direct significant impact on economy at no cost on environment.

Saidi and Mbarek (2016) investigated the role of energy in economic growth in case of nine developed nations using 23 years data set from 1990 to 2013. They identified a one-way causality from energy to real GDPPC for all countries.

Following the Paris conference (COP, 21) on environment and sustainability, Khan et al. (2020) investigated the carbon emission and foreign trade in G7 countries in the context of energy and innovation for the protection of environment. They believed that measurement of carbon emission is important for policies to tackle the problem of environmental quality. They used P&Y's slope heterogeneity test and Pesaran's CD test from a data set of 1990 to 2017. So they proposed the use of renewable energy to attain stable growth with sustainable environment.

Zeren and Akkuş (2020) tried to found the link between energy, trade openness and economic growth in the top emerging countries of Bloomberg in the period of 1980 to 2015 by using Westerlund (2006) panel cointegration test with multiple structural break, Dumitrescu-Hurlin (2012) panel causality test and Pesaran (2006) CCE-MG cointegration. They found that use of energy has direct positive relation with trade openness and economic growth.

Awodumi and Adewuyi (2020) made research about the impact of energy on economic growth and carbon emission in case of African oil producing countries using ARDL estimator from a data set of 1980 to 2015 and found that although nonrenewable energy is useful for the economy of African countries, but in most of cases, it also causes an increase in carbon emission. Coefficients for growth are higher than coefficient for environment degradation so still it is not a major threat for pollution. There was certain variation in results for individual countries in data.

Other writer who worked on energy and economic growth are: Bhattacharya et al. (2016), Jebli et al. (2016), Alper and Oguz (2016), Saidi and Mbarek (2016), Dogan (2016) , Kahia et al. (2017), Rafindadi and Ozturk (2017), Gozgor et al. (2018), Haseeb et al. (2019), Ji and Zhang (2019), Bekun et al. (2019), Charfeddine and Kahia (2019), Sharif et al. (2019), Alam and Murad (2020), Sharif et al. (2020), Ike et al. (2020).

2.2 Role of Capital formation and labour

Shabaz et al. (2017) examined the role of capital formation, labour and energy consumption on the GDP of India from a data set of 1960 to 2015. To investigate the asymmetric cointegration between the variables, the ARDL bounds testing approach was applied. They concluded that there is an asymmetric influence of energy consumption and financial development on economic growth whereas capital formation has systematic positive impact on the economy. They proposed that labour force and the growth exhibit neutrality.

Bosma et al. (2018) studied the importance of capital formation and institution on the economy of South Africa by incorporating the parsimonious growth model in 3SLS specification and found a significant association between institution, capital formation and economic growth.

Tomiwa et al. (2020) put their efforts on ongoing debate in Nigeria about foreign aid and economic growth by using Wavlet analysis to incorporate the effects of explanatory variable like foreign aid, capital formation, trade, labour and inflation rate. They used data set of 1980 to 2018 for Wavlet estimation and found that there is a long term impact of independent variables and economic growth is significantly improved by the factors. Results of wavelet are also sported by the Toda-Yamamoto causality test results.

2.3 CPI and Economic Growth

Behera and Mishra (2017) concluded, by using spline regression method, that threshold level of inflation with growth is 4% in case of India and any increase in rate cause economic growth to fall.

Ndoricimpa et al. (2017) examined the nonlinearity of inflation with growth in case of Africa. They found that inflation that inflation threshold is 6.5% for middle income countries where as it is 9% for poor countries and 6.7% for whole African nations

Chu et al. (2017) identified that inflation rate threshold for economic growth in case of USA is consistent at 3% that is necessary for economic growth.

Mishchenko et al. (2018) identified that Inflation has asymmetric impact on the economic growth of 157 countries and the threshold level for the world is 6% in 2017. Higher than this has negative impact and lower than this has positive impact on the GDP.

2.4 Real exchange rate and Economic Growth

Lee and Brahmasrene (2020) concluded that there is no short term significant relationship between exchange rate and growth in case of China in the presence of structural break in 2008.

Popov and Jomo (2020) concluded that the exchange rate devaluation in case of China was important in last four decades for the economic growth but rapid increase in wage rate, growing domestic demand and slow international trade has undermined its impact.

3. DATA AND METHODOLOGY

3.1. Sample of study and Model Framework

As the aim of this study is to examine the impact of energy consumption on the economic growth of top three economies of the world; USA, China and Japan so a same model is constructed for the analysis purpose. This study has taken data from 1985 to 2020 to estimates the impact of independent variables on the economic growth of the selected countries.

3.2. Estimation Techniques

This study has used Autoregressive distributed lag technique. ARDL can be used for mix order of integration as this study has taken three countries and their individual and comparative order is different so there is need to apply a technique that can be used for mix order of integration. Besides this, the number of observation are roughly 35 and for such time period ARDL is more suitable technique. The same model is formulated for developing and developed countries.

$$lngdppc = \beta 0 + \beta 1 lneup + \beta 2 lngcf + \beta 3 lnlf + \beta 4 cpi + \beta 5 reer + \mu$$

Table 1: Variable Description

Variable Name	Symbol	Brief Description	Source
Economic Growth	lngdppc	Gross domestic product (Constant) per capita	WDI, the world Bank
Energy	lneup	Energy use (kg of oil equivalent per capita)	WDI, the world Bank
Labour Force	lnlf	Labour force as a percentage of population	WDI, the world Bank
Gross capital formation	Lngcf	Gross capital formation	WDI, the world Bank
Inflation	cpi	Consumer price index	WDI, the world Bank
Real exchange rate	reer	Real effective exchange rate	WDI, the world Bank

4. RESULTS AND DISCUSSION

Correlation matrix is shown in tables 2, that indicates the strength of relationship among variables. Its positive sign indicates direct relation and the negative sign indicates inverse relation among variables.

Table 2: Results of Correlation Matrix

		LNEUP	LNGCF	LNLF	CPI	REER
USA	LNEUP	1				
	LNGCF	0.64005	1			
	LNLF	-0.65314	-0.34037	1		
	CPI	-0.73239	-0.45193	0.1980867	1	
	REER	0.369298	0.576203	-0.073087	-0.192516	1
China	LNEUP	1				
	LNGCF	0.180983	1			

	LNLF	0.36542	0.692036	1		
	CPI	0.191693	0.612773	0.197765	1	
	REER	0.401527	0.321883	0.30004	0.251248	1
	LNEUP	1				
	LNGFCF	-0.0149	1			
Japan	LNLF	-0.08837	0.293003	1		
	CPI	0.598821	-0.4538	-0.38608	1	
	REER	0.26575	0.653544	0.648288	-0.33662	1

Table 3 indicates the strength of relationship among variables. All the values are less than ten that is evident of non multi collinearity.

Table 3: Results of Variance Inflation Factor

		LNEUP	LNGCF	LNLF	CPI	REER
	LNEUP	1				
	LNGCF	21.8452	1			
USA	LNLF	1.743994	1.131035	1		
	CPI	2.157071	1.256667		1	
	REER	1.15411	1.55987	1.00537	1.038489	1
	LNEUP	1				
	LNGCF	1.033864	1			
China	LNLF	1.15411	1.919068	1		
	CPI	1.038148	1.601257	1.040703	1	
	REER	1.192213	1.115584	1.09893	1.067379	1
	LNEUP	1				
	LNGFCF	1.000222	1			
Japan	LNLF	1.007871	1.093913	1		
	CPI	1.559057	1.259342	1.175168	1	
	REER	1.07599	1.745566	1.724963	1.127794	1

Unit root tests are prepared to identify the stationarity of data and table 4 indicates that there is mix order. For USA all variables are non-stationary at level and stationary at first difference. There is mix order for China and Japan. Table 5 indicates the suitability of ARDL cointegration technique for estimation.

Table 4: Results of Unit Root Test

		t-stat	p value	t-stat	p value	Decision
China	LNGDPPC	-1.59605	0.4753	-2.63076	0.001	1(1)
	LNEUP	-0.1016	0.9423	-3.11378	0.0337	1(1)
	LNGCF	-1.68295	0.432	-4.66088	0.0006	1(1)
	LNLF	-4.78681	0.0004	-2.73076	0.001	1(0)
	CPI	-1.92877	0.3157	-2.61604	0.01	1(1)
	REER	-4.14426	0.0023	-4.30275	0.0015	1(0)
USA	LNGDPPC	-1.89477	0.3314	-3.92592	0.0044	1(1)
	LNEUP	-1.55707	0.4948	-5.24548	0.0001	1(1)
	LNGCF	-2.31242	0.1731	-5.54393	0.0000	1(1)
	LNLF	-0.87216	0.7848	-3.34718	0.0206	1(1)
	CPI	-1.8246	0.3636	-3.34848	0.0193	1(1)
	REER	-2.05349	0.2639	-4.07285	0.0029	1(1)
Japan	LNGDPPC	-1.98611	0.4258	-3.98611	0.0042	1(1)
	LNEUP	-2.55291	0.1125	-5.22827	0.0001	1(1)
	LNGCF	-0.71427	0.8298	-3.83807	0.0062	1(1)
	LNLF	-0.91542	0.771	-3.48464	0.0148	1(1)
	CPI	-2.88914	0.0571	-3.17117	0.0309	1(0)
	REER	-1.32961	0.6044	-4.43905	0.0013	1(1)

Existence of ARDL co-integration is tested in Microfit 5.5 and table 5 indicates that there is co-integration in the model of all three countries. Co-integration is evident if the value of F-test is higher than the upper bound value at 95% and or 90%. In the given table, model has long term relation of variables in all three countries.

Table 5: Results of ARDL Cointegration Approach

	F-Test	W-Test	R- Square
USA	5.24	31.48	0.998
China	12.9334	77.6005	0.9998
Japan	4.75	28	0.989

Note: 95% Upper Bound (4.4), 90% Upper Bound (3.7) and max of W-test upper Bound limit is 26.

The Long-term impact of explanatory variables is given in table 6 for each country under given specification.

Table 6: Long Run Results

	USA (101010)		China (101001)		Japan (101110)	
Variables	Coefficients		Coefficients		Coefficients	
Energy	.30930	**	.21477	**	.40686	**
Gross Capital formation	.20651	***	-.058257	--	-.38502	-
Labour Force	.84200	***	1.3687	***	1.0122	***
CPI	.0046594	***	.0063703	***	-.0025628	***
Real exchange rate	.0011151	**	.0061272	***	.0050921	--
C	-9.0393	*	-22.0963	***	4.1 845	

*** indicates significance at 99%, ** 95% and * shows significance at 90%

Energy use per capita is taken as a proxy for energy consumption and higher beneficiary is japan where 1% increase in energy consumption leads to increase in GDPPC by 0.4% where as for USA it is 0.3% and for China, rise in GDPPC is 0.21%. Interestingly, these impacts are significant at 95% for all countries. Energy use can cause economic growth by facilitating production of goods and services. Most of the production of goods and services are done through capital intensive methods of production that require energy to operate so more use of energy means more production of goods and services that leads to increase in economic growth. Energy also play role to facilitate business and trade, being used in transportation and keeping offices alive through electricity.

Various scholars have identified the relationship of energy and economic growth such as Bhattacharya et al. (2016), Jebli et al. (2016), Alper and Oguz (2016), Saidi and Mbarek (2016), Dogan (2016) , Kahia et al. (2017), Rafindadi and Ozturk (2017), Gozgor et al. (2018), Haseeb et al. (2019), Ji and Zhang (2019), Bekun et al. (2019), Charfeddine and Kahia (2019), Sharif et al. (2019), Alam and Murad (2020), Sharif et al. (2020), Ike et al. (2020)

Capital is the basic factor of production that has positive impact on economic growth as its rise, cause more production of goods and services. Choice of proxy is important for the determination of impact of the variable. This study has used gross capital formation and that is initial investment but the economic growth is subject to net capital investment. Economic literature suggests that if depreciation of existing capital is higher than gross investment, net benefit will fall and this is evident in case of China and Japan, where 1 %

increase in gross capital formation leads to fall in economic growth by 0.05% and 0.38% respectively. These results are not significant so actual effect may be different. But gross capital formation has positive impact on the economic growth of USA and 1% increase in gross capital formation can cause economic growth by 0.2%, significantly.

Labour is the main factor of production and is endogenous variable in Cobb- Douglas production function so obviously has a positive impact on economic growth. 1% increase in labour force increases GDPPC in USA by 0.84%, China by 1.3% and such rise in GDPPC in Japan is 1.0%. All the results are based on 99% significance level. Higher impact of labour in case of China is because of their huge labour force of around one billion and simply one percent rise in labour force means 10 million more workers to put their efforts on production. Higher coefficient of labour in case of Japan is because of their higher productivity. Efficiency of the labour force of Japan can be seen in the fact that a small size country without natural resources is the third largest economy.

Various scholars have identified the relationship of capital formation, labour and economic growth such Shabaz et al. (2017), Bosma et al. (2018) , Tomiwa et al. (2020)

CPI has a significant and positive impact on the economic growth of USA and China where as it has negative impact on the GDPPC of Japan. 1 unit increase in CPI causes increase in economic growth in USA by 0.0047%, China by 0.006% and there is fall in GDPPC of Japan by 0.00256%. all the results are significant at 99%. Coefficients of CPI are small because of less fluctuation of prices in all economies. Behera and Mishra (2017) , Ndoricimpa et al. (2017) , Chu et al. (2017) , Mishchenko et al. (2018) have identified similar results. Real effective exchange rate plays a negligible positive role in case of USA, China and Japan. 1% increase in rate can cause economic growth by 0.0011% in case of USA, 0.006% in case of China and 0.005% in case of Japan. Coefficients are significant in case of USA and Japan but for Japan it is insignificant. Shu-ping (2017), Su and Wu (2017), Barguellil et al. (2018), Vorlak et al. (2019), Lee and Brahmasrene (2020), Popov and Jomo (2020) have identified similar results.

Table 7: Results of Short Run Analysis

	USA (101010)	China (101001)	Japan (101110)
Variables	Coefficients	Coefficients	Coefficients
dLNEUP	.12180	-.091228 **	.14946 ***
dLNGCF	.21899 ***	.024745 --	.31438 ***
dLNLF	.33157 ***	2.7303 ***	.37182 --
dCPI	.0050492 ***	-.0027059 ***	-.00091 --
dREER	.000433 **	-.0013329 ***	.0018 ***
ecm(-1)	-.39379 ***	-.42476 ***	-.36735 ***

*** indicates significance at 99%, ** 95% and * shows significance at 90%

Energy use has positive and significant use in case of USA and Japan but in case of China it has negative impact.1% increase in energy use, increases GDPPC by 0.14% significantly in case of Japan and 0.12% in case of USA. In case of China, 1% increase in energy use can cause GDPPC to fall by negligible value of 0.091%, significantly.

Japan is most beneficiary in case of gross capital formation as one percent increase in gross capital formation leads to increase in GDPPC by 0.32%, where as for USA, such increase is 0.21%. both results are at 99% significant level. Whereas, for China, such increase is 0.024% insignificantly.

Labour force has significant positive impact on the economic growth of USA and China and positive but insignificant in case of Japan. One percent increase in labour force can cause GDPPC to rise by 0.33% in case of USA and 2.7% in case of China. There is 0.37% rise in case of Japan but that is insignificant. In all the countries, jobs are readily available so in even in short run, they can get benefit from increased labour force.

CPI has positive and significant impact on the GDPPC of USA, but negative and significant in case of China and insignificant negative in case of Japan. One percent increase in CPI causes GDPPC to increase by 0.005% in case of USA and fall by 0.0027% in case of China and 0.0009% in case of Japan. Over-all, short-term impact of CPI is negligible.

One percent increase in real effective exchange rate increases GDPPC by 0.0004% in case of USA, 0.0018 percent in case of Japan but China's GDPPC falls by 0.0013%. All coefficients are significant.

Most of the variables for USA, China and Japan shows the significant impact on the economic growth of country. Labour, capital and energy use have larger impact but CPI and exchange rate have smaller impact.

ECM (-1) shows the speed of adjustment of economic shock and revival of economy to long run equilibrium. This study suggest that long run equilibrium will be restored in USA in 2.54 years, China takes 2.35 years and Japan takes 2.72 years to recover, all at 99% significant level.

Table 8 indicates various diagnostic tests for the model. Serial correlation test indicates whether there is autocorrelation in the model or not. As indicated by the table, p value is higher than 0.1 in the USA, China and Japan so it is concluded that there is no problem of auto correlation in the suggested model.

Table 8: Diagnostics

Test Statistics	USA LM Version	China LM Version	Japan LM Version
Serial Correlation	.80998[.368]	2.3194[.128]	.060159[.806]
Functional Form	55407[.457]	1.0604[.303]	.79097[.374]
Normality	.46977[.791]	.65050[.722]	1.7162[.424]
Heteroscedasticity	.48300[.487}	.60848[.435]	.96976[.325]

Similarly, the functional form is also correctly specified in all three countries as p value is higher than 0.1 so we need to accept the null of correct specification. There is also normal distribution of data as indicated by normality test and also no problem of heteroscedasticity in all three countries.

5. CONCLUSION AND POLICY OPTIONS

Energy is significantly important for the economic growth of USA, China and Japan in short run as well as in long run. Largest beneficiary is Japan, followed by USA and China in long run where as in the short run Japan is highest beneficiary followed by USA but China has inverse relation although coefficient is negligible.

Labor force has positive impact on the economic growth of all countries in short run as well as in long run. Here highest beneficiary is China, followed by Japan and then USA in the long run as well as in the short run, order is same. In the short run, gross capital has positive significant contribution in the economic growth of Japan and USA and China (stated in order) but coefficient in case of China is insignificant.

CPI has significant and positive impact on the economic growth of USA and China as it is stable but in case of Japan it has negative impact, although coefficient is negligible. In short run, CPI has positive and significant impact on the USA and negative impact in case of China and Japan.

Real exchange rate has positive contribution in case of USA, China and japan and the highest beneficiary is China, followed by Japan and USA. Coefficient in case of USA and China is significant but in case of Japan, it is insignificant. In the short run it has positive impact on the economy of Japan and USA but in case of China its effect is negative.

Energy consumption is vital for the economic growth of USA, China and Japan so there is need to continue its consumption although they should convert their resources from non-renewable to renewable energy consumption to avoid its negative consequences on the environment.

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