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The Impact of Energy Consumption, Energy Intensity, and Greenhouse Gas Emissions on Sustainable Development in ASEAN Countries

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Abstract:
This study investigates the impact of energy consumption, energy intensity, and greenhouse gas emissions on sustainable development in 10 ASEAN countries over the period 2000-2021. Using panel data regression analysis, the research identifies the extent to which these environmental and energy-related variables influence sustainable development indicators. The fixed effect model (FEM) was selected as the most appropriate specification based on the results of Chow, Hausman, and Lagrange Multiplier tests. The findings reveal that energy consumption and greenhouse gas emissions negatively affect sustainable development, while energy intensity has a positive and significant impact. These results highlight the urgent need for ASEAN countries to adopt cleaner energy strategies and improve energy efficiency to promote sustainable growth. The study offers valuable insights for policymakers in balancing economic growth and environmental sustainability in the region.

JEL: Q44; Q01; Q43; C33

Keywords:
sustainable development; energy consumption; energy intensity; greenhouse gas emissions; ASEAN; panel data; environmental economics

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1. Introduction

Numerous developed and developing nations are undergoing swift demographic shifts, particularly characterized by population aging and declining birth rates. This process affects many areas of the economy, especially national consumption, which is part of GDP calculation using the expenditure approach. This issue is of great importance for economic stability and the actors within a country. Although depopulation seems to be a recent phenomenon, it is in fact a process deeply rooted in history (Alonso et al., 2023). Demographic forecasts show that, compared to 2019, by 2026 the population of the European Union (EU-27) will decline by approximately 1.3%, and by 2100 nearly 7% (Eurostat, 2020). These population changes are not expected to occur as quickly as changes in age structure caused by increased life expectancy and EU migration. Depopulation intensity also varies across the EU-27 regionally (although a country may have an overall declining population, some regions may experience growth).

Compared to other European countries, population aging is a more certain and structured process. A longer life expectancy and a shift toward older populations will influence household behavior and the economic structure, particularly with respect to productivity and consumption levels.

Japan is a classic example of a country with a long-term population decline due to low birth rates and high life expectancy. As Japan experiences rapid demographic aging, the country is forced to innovate economically and socially to maintain a high standard of living and sustainable consumption. Consumption behavior is influenced by age demographics. Aging populations tend to save more and consume less due to concerns about future uncertainties, especially health and retirement. Meanwhile, in younger populations, consumption tends to be more dynamic, reflecting higher economic optimism.

The logic used in the research: if population decline is accompanied by increasing aging, it may lead to lower overall consumption. Furthermore, the fertility rate is used as a proxy for future population growth. Lower fertility is associated with fewer births and potential decreases in future consumption. On the other hand, GDP per capita is used as an economic prosperity indicator, affecting individual and household consumption capacity. This study integrates these variables into a panel data regression model to explore the relationship between demographic change and national consumption across countries and over time.

2. Literature Review

John Maynard Keynes's Consumption Theory: in his theory, Keynes relied on statistical analysis and also made assumptions about consumption based on introspection and casual observation. First and foremost, Keynes assumed that the marginal propensity to consume (MPC) the amount consumed from each additional unit of income–is between zero and one. The marginal propensity to consume is crucial to Keynes’s policy recommendation for reducing widespread unemployment. The strength of fiscal policy in influencing the economy, as demonstrated by the fiscal policy multiplier, arises from the feedback loop between income and consumption.

Second, Keynes proposed that the average propensity to consume (APC) the ratio of consumption to income declines as income rises. He viewed saving as a luxury, suggesting that wealthier individuals tend to save a greater portion of their income compared to those with lower incomes.

Third, Keynes emphasized that income is the primary factor influencing consumption, while interest rates have a minimal effect. He argued that, in the short term, interest rates have only a minor and secondary influence on how individuals spend their income.

Based on these three assumptions, Keynes's consumption function is often written as:

$$\mathbf{C = a + bY}$$

Where:

C = consumption
Y = disposable income
a = autonomous consumption
b = marginal propensity to consume (N. Gregory Mankiw, 2016)

From this consumption function, Keynes proposed several assumptions regarding the theory of consumption, as follows:

1. The marginal propensity to consume is the portion of income that is consumed, and it lies between zero and one. This implies that as an individual’s income increases, their consumption and saving will both increase.

2. The average propensity to consume, or the ratio of consumption to income, decreases as income rises because a portion of the additional income is allocated to savings. According to Keynes, the saving behavior of the wealthy differs from that of the poor. The rich tend to save more in absolute terms than the poor.
3. Income is a key determinant of consumption, while interest rates are not significantly influential. Based on Keynes's theory, one can conclude that a person's consumption level is strongly influenced by their income level.

To summarize, here are some notes on Keynes's consumption function:

1. The real variable is that Keynes's consumption shows the relationship between national income and consumption expenditure, both of which are expressed at constant price levels.
2. Current income: It is stated that national income determines the level of consumption expenditure.
3. Absolute income: Keynes's consumption function interprets national income as absolute income, which can be contrasted with relative income, permanent income, etc.
4. The form of the consumption function is a straight line. However, Keynes believed the actual consumption function was curved (Ragandhi, 2012).

3. Variable Description

Dependent Variable:

Final consumption expenditure, expressed in constant 2015 US dollars, combines household and government spending on goods and services (World Bank).

Independent Variables:

1. Net National Income (NNI)
   Adjusted Net National Income (NNI) extends Gross National Income (GNI) by factoring in the depletion of natural resources, offering a more comprehensive measure of economic progress. It is derived by subtracting fixed capital consumption and natural resource depletion such as forest, energy, and mineral resources from GNI. This depletion is treated similarly to depreciation of fixed assets. The growth of adjusted NNI is based on constant prices and deflated using the gross national expenditure deflator (World Bank).
2. Population
   Population definition counting all residents regardless of legal status and represent mid-year estimates (World Bank).
3. Tax Revenue
   Tax revenue includes mandatory transfers to the central government for public spending, excluding fines, penalties, most social security contributions, and refunds or tax corrections treated as negative revenue (World Bank).

4. Fertility Rate
   The total fertility rate represents the number of children a woman would bear if she were to live through the end of her childbearing years and give birth according to the age-specific fertility rates of a given year.World Bank)

Variable		Mean	Std. dev.	Min	Max	Observations	
lC	overall	25.78494	1.814769	23.6455	28.854	N =	84
	between		1.947081	23.78649	28.83345	n =	7
	within		.0685513	25.62764	25.94921	T =	12
lincome	overall	25.80745	1.819606	23.57704	28.92875	N =	84
	between		1.951367	23.77579	28.8749	n =	7
	within		.0882183	25.60871	25.97983	T =	12
lpop	overall	16.21248	1.450681	14.44917	18.66809	N =	84
	between		1.557377	14.4957	18.66023	n =	7
	within		.0222675	16.14295	16.27897	T =	12
tax	overall	20.41266	4.73108	8.721431	27.19683	N =	84
	between		4.888558	10.97153	24.93661	n =	7
	within		1.285427	15.61623	24.45899	T =	12
fer	overall	1.453214	.1226039	1.23	1.74	N =	84
	between		.0922261	1.345833	1.580833	n =	7
	within		.0874832	1.219881	1.629881	T =	12

Variable	Obs	Mean	Std. dev.	Min	Max
lC	84	25.78494	1.814769	23.6455	28.854
lincome	84	25.80745	1.819606	23.57704	28.92875
lpop	84	16.21248	1.450681	14.44917	18.66809
tax	84	20.41266	4.73108	8.721431	27.19683
fer	84	1.453214	.1226039	1.23	1.74

4. Econometrics Model

$$Ln\,C = \propto_0 + \beta_1\, lincome_{it} + \beta_2 lpop_{it} + \beta_3\, tax_{it} + \beta_4\, fer_{it} + \varepsilon_{it}$$

Dependent variable is Ln Consumption, with a mean value of 25.78494 and independent variables are as follows: X1 represents log income with a mean of 25.00745; X2 represents log population with a mean of 16.21248; X3 represents tax with a mean of 20.41266; and X4 represents fertility rate with a mean of 1.453214.

5. Result

1. Chow Test

Chow Test is used to choose between the Ordinary Least Squares (OLS) model and the Fixed Effect (FE) model, with hypotheses:

H_0: The appropriate model is the OLS model (Common Effect Model)
H_1: The appropriate model is the Fixed Effect Model (FE)

lC	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
lincome	1.082547	.0382245	28.32	0.000	1.006463	1.158631
lpop	-.1182878	.0496915	-2.38	0.020	-.2171963	-.0193793
tax	.0007252	.0017442	0.42	0.679	-.0027466	.004197
fer	-.2349659	.0810078	-2.90	0.005	-.3962078	-.0737239
_cons	.0915381	.2632612	0.35	0.729	-.4324701	.6155464

lC	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
lincome	.7426168	.0414282	17.93	0.000	.6600506	.825183
lpop	.0089048	.177184	0.05	0.960	-.3442224	.3620319
tax	-.0073828	.0021394	-3.45	0.001	-.0116467	-.0031189
fer	.0719903	.0291185	2.47	0.016	.0139572	.1300234
_cons	6.521605	3.700087	1.76	0.082	-.8526578	13.89587
sigma_u	.48382401					
sigma_e	.01970971					
rho	.99834322	(fraction of variance due to u_i)				

F test that all u_i=0: F(6, 73) = 124.79 Prob > F = 0.0000

Based on the results of the Chow Test, the value of Prob > F is 0.0000, which is less than the significance level α = 0.05. Therefore, H_1 is accepted, indicating that the best model to use is the Fixed Effect Model. This conclusion is drawn by referring to the Prob > F value located at the bottom of the Fixed Effect output result.

2. Hausman Test

Hausman Test is a follow-up test used in selecting the appropriate panel data regression model. It is conducted when the Chow Test indicates that the Fixed Effects Model performs better. The Hausman Test is then applied to determine which model is more suitable between the Fixed Effects Model and the Random Effects Model. The hypotheses is:

H_0: The appropriate model is the Random Effects Model
H_1: The appropriate model is the Fixed Effects Model

lC	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
lincome	.8009521	.0278377	28.77	0.000	.7463913	.8555129
lpop	.2419835	.0377915	6.40	0.000	.1679135	.3160535
tax	-.0044437	.0020245	-2.19	0.028	-.0084117	-.0004758
fer	.0616754	.0341246	1.81	0.071	-.0052075	.1285583
_cons	1.192331	.2457721	4.85	0.000	.7106268	1.674036
sigma_u	.03846338					
sigma_e	.01970971					
rho	.79202755	(fraction of variance due to u_i)				

	---- Coefficients ----			
	(b) re	(B) fe	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
lincome	.8009521	.7426168	.0583353	.
lpop	.2419835	.0089048	.2330787	.
tax	-.0044437	-.0073828	.0029391	.
fer	.0616754	.0719903	-.0103149	.0177932

```
            =  12.92
Prob > chi2 = 0.0117
            (V_b-V_B is not positive definite)
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In accepting or rejecting the above hypotheses, the Hausman Test follows a Chi-square distribution with degrees of freedom equal to *k*, where *k* is the number of independent variables. If the Hausman test statistic is greater than its critical value, H_0 is rejected and the appropriate model is the Fixed Effects Model. Conversely, if the Hausman test statistic is smaller than the critical value, then the appropriate model is the Random Effects Model (Gujarati, 2008).

In this case, the Hausman Test result between the Random Effects Model (RE) and Fixed Effects Model (FE) shows a probability value of Prob > chi² = 0.0117**,** which is less than 0.05. Therefore, H_0 is rejected and the appropriate model is the Fixed Effects Model**.**

Wald chi2(4) = 11313.56
corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0000

lC	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
lincome	.8009521	.0278377	28.77	0.000	.7463913	.8555129
lpop	.2419835	.0377915	6.40	0.000	.1679135	.3160535
tax	-.0044437	.0020245	-2.19	0.028	-.0084117	-.0004758
fer	.0616754	.0341246	1.81	0.071	-.0052075	.1285583
_cons	1.192331	.2457721	4.85	0.000	.7106268	1.674036
sigma_u	.03846338					
sigma_e	.01970971					
rho	.79202755	(fraction of variance due to u_i)				

Based on the Random Effects Model, the p-value for the variable *lincome* (X1) is 0.000 < 0.01, indicating that income significantly increases consumption (LnC), with a positive coefficient value of 0.0009521. This implies that the higher the income, the greater the consumption. The p-value for the *lpop* (X2) variable is 0.000 < 0.01, showing that population significantly influences consumption (LnC), with a positive coefficient of 0.2419835, meaning an increase in population leads to higher consumption. Both variables—income and population—fall within a 1% confidence interval, which suggests that a 1% increase in income and population would increase consumption by approximately 0.99%.

The *tax* variable (X3) has a p-value of 0.028 < 0.05, indicating that tax significantly affects consumption (LnC), with a negative coefficient of -0.0044437. This implies that an increase in tax would reduce consumption. This falls within a 5% confidence interval, meaning a 1% increase in tax would lower consumption by approximately 0.95%.

The *fer* variable (X4), representing the fertility rate, has a p-value of 0.071 < 0.1, indicating that the fertility rate significantly affects consumption (LnC), with a positive coefficient of 0.0616754. This means that an increase in the fertility ratio would lead to an increase in consumption. With a 10% confidence interval, a 1% rise in the fertility rate would increase consumption by approximately 0.95%.

6. Conclusion

Based on the research findings, it can be concluded that depopulation will affect the aggregate consumption of an economy, which in turn influences GDP through the expenditure approach as an indicator of economic growth. Our findings are expected to be useful for the sustainability of countries currently facing depopulation issues and urge immediate solutions to these demographic challenges, as failure to address them may impact economic stability. Meanwhile, the recommendation for countries not yet facing such demographic issues is to implement preventive measures to avoid experiencing similar problems, which could otherwise negatively affect the national economy and the well-being of their societies.

Table. Data

country	**year**	**C**	**income**	**pop**	**tax**	**fer**
greece	2010	2.12573E+11	1.91357E+11	11121341	20.14018756	1.48
greece	2011	1.95059E+11	1.67873E+11	11104899	22.19142957	1.4
greece	2012	1.81562E+11	1.61155E+11	11045011	24.36768501	1.34
greece	2013	1.7407E+11	1.56475E+11	10965211	24.24668557	1.29
greece	2014	1.73438E+11	1.60744E+11	10892413	24.98251258	1.3
greece	2015	1.74053E+11	1.62793E+11	10820883	25.08832866	1.33
greece	2016	1.73195E+11	1.62609E+11	10775971	26.93155788	1.38
greece	2017	1.7608E+11	1.64867E+11	10754679	26.75302357	1.35
greece	2018	1.77062E+11	1.65814E+11	10732882	27.19683229	1.35
greece	2019	1.80489E+11	1.70343E+11	10721582	26.1236294	1.34
greece	2020	1.71314E+11	1.53683E+11	10698599	25.30182863	1.39
greece	2021	1.79533E+11	1.67039E+11	10569207	25.91564922	1.43
Jepang	2010	3.21054E+12	3.29393E+12	128070000	8.721430513	1.39
Jepang	2011	3.21598E+12	3.26907E+12	127833000	9.245331531	1.39
Jepang	2012	3.27835E+12	3.32028E+12	127629000	9.577547077	1.41
Jepang	2013	3.35428E+12	3.40987E+12	127445000	10.24989945	1.43
Jepang	2014	3.33982E+12	3.42195E+12	127276000	11.36180613	1.42
Jepang	2015	3.35097E+12	3.56075E+12	127141000	11.28432252	1.45
Jepang	2016	3.35447E+12	3.61055E+12	127076000	10.98495383	1.44
Jepang	2017	3.3812E+12	3.66097E+12	126972000	11.47622466	1.43
Jepang	2018	3.39591E+12	3.64739E+12	126811000	11.70348136	1.42

Jepang	2019	3.39728E+12	3.63371E+12	126633000	11.42940771	1.36
Jepang	2020	3.30826E+12	3.43841E+12	126261000	12.31570769	1.33
Jepang	2021	3.35804E+12	3.39451E+12	125681593	13.30827111	1.3
Kroasia	2010	42262732010	41491217637	4295427	20.3197806	1.46
Kroasia	2011	42802010747	40777709093	4280622	19.68382908	1.41
Kroasia	2012	41880409561	39356674309	4267558	20.17730217	1.52
Kroasia	2013	41462660337	39792860903	4255689	20.68785648	1.46
Kroasia	2014	40863615505	39623105745	4238389	20.4230395	1.46
Kroasia	2015	40924971514	42022305888	4203604	21.41114241	1.41
Kroasia	2016	41984332530	43138287967	4174349	21.86675079	1.43
Kroasia	2017	43191463175	45835452151	4124531	22.00739597	1.42
Kroasia	2018	44508386599	47706177827	4087843	21.73934965	1.47
Kroasia	2019	46160329832	49532110450	4065253	21.83110435	1.47
Kroasia	2020	44883301139	44289715369	4047680	20.78143895	1.48
Kroasia	2021	48620121224	49127682262	3878981	20.89061415	1.62
Hungary	2010	81240568140	87857168571	10000023	22.4508027	1.25
Hungary	2011	81823171310	88218208032	9971727	20.85822015	1.23
Hungary	2012	80192215371	86651053555	9920362	22.52494781	1.34
Hungary	2013	80785372271	90641876447	9893082	22.56334636	1.35
Hungary	2014	83345214037	94131645266	9866468	22.72484251	1.44
Hungary	2015	86063791360	98263129324	9843028	22.90928987	1.45
Hungary	2016	89140683594	1.03487E+11	9814023	22.75236831	1.53
Hungary	2017	93031308566	1.05954E+11	9787966	22.54833047	1.54
Hungary	2018	96893945388	1.11379E+11	9775564	22.20190929	1.55
Hungary	2019	1.01993E+11	1.18712E+11	9771141	22.10911955	1.55
Hungary	2020	1.01127E+11	1.13405E+11	9750149	22.60773024	1.59
Hungary	2021	1.04917E+11	1.16727E+11	9709891	21.25062565	1.61
Italy	2010	1.53779E+12	1.55257E+12	59277417	23.68062299	1.46
Italy	2011	1.53061E+12	1.54774E+12	59379449	23.64758929	1.44
Italy	2012	1.48078E+12	1.48748E+12	59539717	24.94682979	1.43

Italy	2013	1.44929E+12	1.46461E+12	60233948	25.13890393	1.39
Italy	2014	1.44897E+12	1.48016E+12	60789140	24.84107219	1.37
Italy	2015	1.46709E+12	1.49006E+12	60730582	24.73952717	1.35
Italy	2016	1.48334E+12	1.54807E+12	60627498	25.07030955	1.34
Italy	2017	1.50049E+12	1.57499E+12	60536709	24.68367944	1.32
Italy	2018	1.51143E+12	1.59808E+12	60421760	24.2381807	1.29
Italy	2019	1.51166E+12	1.60435E+12	59729081	24.5767049	1.27
Italy	2020	1.39188E+12	1.45301E+12	59438851	24.75958016	1.24
Italy	2021	1.45298E+12	1.54269E+12	59133173	25.04853906	1.25
Lithuania	2010	28327194404	28990819351	3097282	15.96497347	1.5
Lithuania	2011	29236864051	30137163748	3028115	15.48237695	1.55
Lithuania	2012	30020905774	31069282801	2987773	15.52996015	1.6
Lithuania	2013	31076864696	32444577223	2957689	15.60121464	1.59
Lithuania	2014	32001467278	34198417311	2932367	15.83633785	1.63
Lithuania	2015	33035421231	34402653749	2904910	16.69486269	1.7
Lithuania	2016	34104036367	35711495169	2868231	16.93159775	1.69
Lithuania	2017	35036619675	37503103028	2828403	16.65064705	1.63
Lithuania	2018	36060157521	38904585396	2801543	16.78390655	1.63
Lithuania	2019	36819706746	40704019282	2794137	19.9659267	1.61
Lithuania	2020	35746932047	41002457668	2794885	19.98001451	1.48
Lithuania	2021	38052417729	41689026374	2800839	21.27070937	1.36
Latvia	2010	18582703277	17353206312	2097555	19.64705897	1.36
Latvia	2011	18642401728	17911521619	2059709	20.58808651	1.33
Latvia	2012	19479963023	18749291903	2034319	21.06339396	1.44
Latvia	2013	20528034418	19409904192	2012647	21.73241997	1.52
Latvia	2014	20818960903	19829889228	1993782	22.02707856	1.65
Latvia	2015	21249809168	20674751442	1977527	22.36245952	1.7
Latvia	2016	21921958734	21862793902	1959537	23.47434266	1.74
Latvia	2017	22591111506	22850123871	1942248	23.44696296	1.69
Latvia	2018	23209477435	23909103598	1927174	22.78903446	1.6

Latvia	2019	23511991672	24311239401	1913822	21.29940673	1.61
Latvia	2020	22868241197	23906713957	1900449	21.8576863	1.55
Latvia	2021	24307564561	25150994891	1884490	22.09251388	1.57

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