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Exports, FDI Inflows, Renewable Energy and Economic Growth: An Empirical Evidence from Singapore

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Abstract
The present study captures the impact of exports; FDI inflows and renewable energy on economic growth of Singapore economy by covering time period 1989-2022 in the context of Cobb-Douglas production function. This study applies ARDL approach for obtaining empirical results. The estimated results will further be tested by taking most of the diagnostic tests to make check whether the results are robust or not. The findings of this study reveal that exports; FDI inflows and renewable energy have a positive and statistically significant impact on the economic growth. However, short run impact of renewable energy is witnessed as insignificant while exports and FDI inflows contribute significantly in boosting economic growth. Moreover, labor and capital also play a positive role in enhancing economic growth. Based on these findings; this study suggests that exports; FDI inflows, and renewable energy may be given more importance by expanding their size if domestic production in Singapore is required to be increased.
Keywords: Economic Growth, Exports, FDI Inflows, Renewable Energy, ARDL, Singapore

1. Introduction

In today's global market, economic growth remains a top priority for national governments, regional coalitions, and international organizations. Moreover, the argument around economic growth is increasingly intertwined with the principles of sustainable development, emphasizing the responsible utilization of global resources for the benefit of future generations. The utilization of non-renewable energy sources has faced extensive criticism due to its unsustainable nature and substantial carbon emissions. As the issue of climate change has gained prominence and awareness regarding environmental conservation has grown, the significance of transitioning to renewable energy sources has become increasingly apparent. Wang et al. (2020) highlight this shift in focus towards renewable energy consumption. With the rise in adoption of renewable energy sources, researchers have turned their attention to studying this phenomenon, as noted by Wang et al. (2021), particularly emphasize the connection among economic growth and renewable energy. Hence, it is imperative to advocate for the adoption of new energy sources that foster economic growth without causing harm to the environment. Consequently, industrialized nations are actively involved to consider and utilize renewable energy sources such as tidal hydropower, wing power, geothermal, solar, and biomass.

Moreover, we visited many scholars who suggested different factors that impact economic growth in different sample economies [Hanif et al. (2014; 2020); Alharthi and Hanif (2020); Wang et al. (2022); Huang et al. (2020) and Farhadi and Zaho, 2024]. Afterwards, Nazli et al. (2018) tested the determinants of total factor productivity while carbon emission's determinants were found by Hanif (2018), Hanif and Gago-de Santos (2017) and Roussel and Audi (2024) reported the factors influencing private savings. Romer (1986) and Lucas (1988), are the pioneer of the endogenous growth model and postulate that a lasting development in economic growth rates hinges the idea of consistent and escalating returns to capital. Similarly, Barro and Lee (1994) empirically examine the association between human capital and economic growth, giving support to Romer's (1990) assertion regarding the pivotal role of human capital in driving economic development. Fischer (1993) contends that sustained economic growth is inversely related to inflation while positively associated with foreign exchange markets. While production functions in the neoclassical tradition typically use capital and labor inputs, they do not consider energy as an input factor. However, energy crisis in history highlighted the critical relationship between energy and economic growth. So, some researchers are encouraged by this notion such as Brockway et al. (2017), to include energy in the production function. Additionally, Behera and Mishra (2020) pointed out energy consumption link with economic growth. Numerous factors contribute to GDP, including optimal allocation of technological resources, capital and labor, innovations and energy. This study endeavor to apply production function proposed by Cobb-Douglas to gauge the effects of exports; FDI inflows, renewable energy, labor and capital on economic growth of Singapore. This study considers an annual data series from 1989 to 2022 for obtaining empirical results.

The rest of the paper covers literature review, section 3 of the paper deals with data model and methodology, section 4 comprises of results and interpretation while section 5 of paper is dedicated to conclusion and proposed policy recommendations.

2. Literature Review

This section provides insights on the possible connection between variables utilized in the model.

Al Nemer et al. (2023) proposed a link between non-renewable and renewable energy, carbon emission and economic growth for Saudi Arabia using Spectral Granger Causality approach. The finding uncovered spread of carbon emission due to sources of non-renewable energy and sources of renewable energy reduces carbon emission leading to high economic growth. The utilization of renewable energy significantly reduces carbon emissions and fostering short-term economic growth. Analysis through multiple wavelet approaches suggests that renewable energy not only boosts economic activity but also fosters a cleaner and more sustainable environment. Gozgor (2018) forwarded a notion that economic growth is influenced by renewable energy consumption. The findings of ARDL model revealed that economic growth is increased by energy consumption. Similarly, Gozgor et al. (2018) examined 29 OECED nations considering renewable, non-renewable energy and economic growth. The data has been analyzed while using panel quintile regression from 1990 to 2013. The results stated that both energy sources enhance economic growth. Shahbaz et al (2020) studied 38 high energy consumption nations from 1990 to 2018. The study examined the impact of

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renewable energy consumption and economic growth by using different approaches. The findings confirmed a sustained long-term connection. Additionally, the study observed positive impacts of variable of interest i.e. renewable energy, capital, non-renewable energy and labor on economic growth. Notably, renewable energy consumption positively influences economic growth in 58% of the countries surveyed. Wang and Wang (2020) determined linear association between renewable energy and economic growth ignoring nonlinear impact. The study used fixed effect model for 34 OECD countries from 2005 to 2016. The findings uncovered that renewable energy play a positive role in the uplift of the economic growth, which changes according to changes in the threshold values. Chen et al. (2020) proposed that renewable energy and economic growth have causality. The study has used threshold model for 103 countries covering time span 1995-2015. The study argued that the said relationship is dependent on the usage of energy consumption. Moreover, the outcome of the study revealed that a certain threshold level is required for OECD and developing countries to establish a positive link between the studied variables.

Basegmez (2021) estimated the Cobb-Douglas production function within developing nations, utilizing input factors such as energy consumption, labor and capital. The study used panel data for 22 developing countries ranging from 1980 to 2016. The coefficient of energy consumption is 0.14, the coefficient of capital has shown 0.60 increase and labor has shown 0.45 increase, suggesting that developing economies lean towards capital intensity. The combined share of all production factors amounts to 1.2, indicating increasing returns to scale. Moreover, the study found that capital, labor, and energy consumption inputs all positively influence GDP within these economies. Apinran et al (2022) shed light on the electricity consumption and economic growth, while considering factors such as labor, capital, and CO2. They employed both (ARDL) and Dynamic ARDL (DYNARDL) simulation analyses ranging from 1981 to 2019. The empirical findings revealed that all factors have shown positive and inelastic effects, negative and inelastic effect has been observed in case of carbon emissions on economic growth during the studied period. Iqbal et al. (2023) studied the vital role of FDI and exports on economic growth. The study examined BRICS countries from 2000 to 2018. The results of the study is dependent on multiple regression approaches. The results of PMG support positive impact of FDI and exports on economic growth. This outcome is underpinned by the FMOLS and DOLS outcome. Furthermore, bi-directional causality is detected in the model. Islam (2020) established a relationship between FDI, exports and economic performance. The study endeavor to establish this relationship in Bangladesh from 1986 to 2018 using ARDL approach. The findings revealed that economic growth improves as there is an increase in exports both in short and long run. Moreover, positive causality runs from the earnings of export to economic growth. However, it has also been found that FDI worsen economic growth in the short run but in the long run its impact is insignificant. Rahman and Alam (2021) explored the key determinants of economic growth for 20 largest economies from 1980 to 2018. The study analyzed FDI, international trade, human capital and energy consumption alongside traditional factors such as capital and labor. The study employs panel (ARDL) method with the Pool Mean Group (PMG) estimator, the study also accounted for major diagnostic and panel causality test confirming a long-term relationship among the variables, with all independent variables exhibiting a direct and significant impact on long-term economic growth. In the short term, the coefficients for trade, capital, and energy consumption showed positive and significant effects, while human capital had a negative effect. The study identified a unidirectional causal link from economic growth to energy consumption and FDI. Ciobanu (2020) investigated the relationship between FDI and GDP growth, examining the causality over recent decades. This investigation aimed to determine the long-term relationship between FDI, trade, labor, and economic growth. Additionally, the study specifies the direction of causality. The results indicated cointegration among the variables, highlighting FDI, labor force and trade as key determinants of long-term economic growth. Moreover, an increase in labor force, GDP, exports and imports, is found to foster FDI in the long run. Majumder and Rahman (2020) analyzed the effect of FDI on economic growth of China. Annual time series data has been used from 1982 to 2019. The study used VECM for the analysis purpose. It has been found that in the long run FDI have shown positive impact on economic growth however there exists causality in the short run.

Huong (2022) inspected the role of FDI on Vietnam's economic growth from 1990 to 2020. The study employed the VAR model alongside unit root tests, and Granger causality analysis. The findings suggested that while FDI positively impacts economic growth, it detrimentally affects long-term growth. Despite the consistent increase in FDI capital and its potential, the study highlights the limited effectiveness of FDI. Yimer (2023) investigated FDI on economic growth from 1990 to 2016 for Africa. The study uses dynamically common correlated effect approach. The study classifies African economies into three categories. While FDI has shown positive impact on growth in investment driven and factor driven economies. On the other hand, in fragile economies, both the short-term and long-term effects of FDI on growth are insignificant. Fazaalloh (2024) highlighted the importance of foreign direct investment (FDI) and economic growth. The study used sectoral data from all 33 provinces of Indonesia from 2010 to 2019. The study applied fixed effects to demonstrate a clear and positive relationship between FDI and economic growth Indonesian provinces. Furthermore, our findings indicate that FDI in sectors such as mining, real estate, electricity, water, hotels, gas, and restaurants significantly boosts economic growth. Conversely, FDI in the agricultural sector exhibits a notable negative impact on economic growth. Oncel et al. (2024) probed export performance and indicators of financial development on economic growth in 9 members of the commonwealth from 1995 to 2020. The study used PVAR analysis within a VECM framework, they establish the long-term relationship. FMOLS and DOLS methods are employed for long-term coefficient estimation. Long run relationship has been witnessed between dependent and independent variables. Moreover, positive impact has been observed on economic growth by financial development and exports. However, evidence regarding inconclusive results have been witnessed between gross capital formation and economic growth, while other variables such as monetary sector credit to private sector witnessed negative effects. When the study uses both FMOLS and DOLS models together, it is inferred that exports and financial development positively affect economic growth, the former's effect is relatively weaker.

3. Data, Methodology and Model

The initial step in our methodology involves describing the statistics of the variables extracted from the World Bank (2024)'s dataset, covering the period from 1989 to 2022. Subsequently, we assess the stationarity of these variables through KPSS (1992) unit root test. Prior to applying the Autoregressive Distributed Lag (ARDL) method for further estimation, we conduct bound

testing to ensure its applicability. To address multicollinearity concerns, we employ Variance Inflation Factor (VIF). The study then utilized ARDL approach coined by Pesaran et al. (1999, 2001) to establish relationship among variables in the short and long run. To make the findings of the study robust, the study subject the model to various diagnostic tests, including normality testing, heteroskedasticity testing, serial correlation analysis, and functional form evaluation. This study also applies cusum and cusumsq test to determine the stability of the model.

3.1. Model

Functional form

GDP =f (exports, labor, capital, foreign direct investment, renewable energy).

$$(\ln GDPPC)_t = \beta_0 + \beta_1 (lnGDPPC)_{t-1} + \beta_2 (lnLAB)_{t-1} + \beta_3 (\ln FDI)_{t-1} + \beta_4 (lnEXP)_{t-1} + \beta_5 (\ln CAP)_{t-1} + \beta_6 (\ln RE)_{t-1} + \sum_{i=1}^{n} \delta_i \Delta (lnLAB)_{t-i} + \sum_{i=0}^{n} \varepsilon_i \Delta (\ln FDI)_{t-i} + \sum_{i=0}^{n} \psi_i \Delta (lnEXP)_{t-i} + \sum_{i=0}^{n} \eta_i \Delta (lnCAP)_{t-i} + \sum_{i=0}^{n} \gamma_i \Delta (lnRE)_{t-i} + U_t$$

$$\Delta (lnGDPPC)_t = \beta_0 + \sum_{i=1}^{n} \delta_i \Delta (\ln GDPPC)_{t-i} + \sum_{i=1}^{n} \varepsilon_i \Delta (\ln LAB)_{t-i} + \sum_{i=1}^{n} \psi_i \Delta (\ln FDI)_{t-i} + \sum_{i=1}^{n} \theta_i \Delta \ln(\ln EXP)_{t-i} + \sum_{i=1}^{n} \eta_i \Delta (\ln RE)_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta (\ln CAP)_{t-i} + \lambda (ECM)_{t-1} + U_t$$

4. Results and Interpretation

Table 1: Descriptive Stats

Variables	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Observations
$\ln GDPPC_t$	1.1062	0.0335	-0.3128	1.9044	2.3215	0.3133	35
$\ln LAB_t$	1.4706	0.0299	-0.1909	1.6864	2.7289	0.2555	35
$\ln CAP_t$	0.0334	0.0020	-0.3698	2.3714	1.3738	0.5031	35
$\ln EXP_t$	0.5222	0.0096	0.7354	2.7455	3.2489	0.1970	35
$\ln FDI_t$	0.2791	0.0490	-0.9010	3.2371	4.8178	0.0899	35
$\ln RE_t$	0.0218	0.0326	-1.0622	3.5984	7.1044	0.0287	35

Table 1 presents descriptive statistics for six variables derived from the World Development Indicator from 1989 to 2022. Across the variables, the mean values vary, with the highest mean observed for variable labor force at 1.4706 and the lowest for renewable energy at 0.0218. The standard deviations range from 0.0020 to 0.0490, indicating differing levels of dispersion around the means. Skewness values exhibit variability as well, with the most positively skewed distribution observed in exports (0.7354) and the most negatively skewed in renewable energy (-1.0622). Kurtosis values are also diverse, ranging from 1.6864 to 3.5984, with renewable energy exhibiting the highest kurtosis, suggesting heavy tails in its distribution. Jarque-Bera statistics and their associated probabilities assess normality, if the p values are above the 5% level of significance across all variable this indicate that they do not significantly deviate from a normal distribution. These statistics provide crucial insights into the distributional characteristics of the variables, aiding in understanding their behavior and informing subsequent analytical approaches.

Table 2: VIF Matrix

Variables	$\ln LAB_t$	$\ln CAP_t$	$\ln EXP_t$	$\ln FDI_t$	$\ln RE_t$
$\ln LAB_t$	-				
$\ln CAP_t$	1.5773	-			
$\ln EXP_t$	1.0625	1.3510	-		
$\ln FDI_t$	1.5865	1.3644	1.0563	-	
$\ln RE_t$	2.3201	1.5246	1.0015	1.0952	-

The VIF matrix in Table 2 provides specific insights into the multicollinearity among the variables considered in the analysis. Each cell in the matrix represents the VIF value for a pair of variables. Looking at the diagonal values, we observe that all variables have VIF values less than 10, indicating that the multicollinearity is not severe. Additionally, the off-diagonal values show moderate levels of multicollinearity, with the highest value observed at 2.3201. While this suggests some degree of

correlation between certain pairs of variables, it does not exceed the typical threshold for concern. Overall, the VIF matrix indicates that multicollinearity is not a major issue among the variables, which is crucial for ensuring the reliability of the regression analysis results.

Table 3: KPSS Unit Root Test

At Level		At First Difference	
Variables	LM-Test	Variables	LM-Test
$\ln GDPPC_t$	0.9644	$\Delta \ln GDPPC_t$	0.3791
$\ln LAB_t$	0.9562	$\Delta \ln LAB_t$	0.3193
$\ln CAP_t$	0.5674	$\Delta \ln CAP_t$	0.0793
$\ln EXP_t$	0.2370	$\Delta \ln EXP_t$	0.1053
$\ln FDI_t$	1.0852	$\Delta \ln FDI_t$	0.0501
$\ln RE_t$	0.7858	$\Delta \ln RE_t$	0.1130

The one; five and 10 percent for KPSS test suggests 0.739; 0.463 and 0.347 critical values respectively.

Table 4: Cointegration Test

ARDL Function	$\ln GDPPC_t = f\ (\ln LAB_t, \ln CAP_t, \ln EXP_t, \ln FDI_t, \ln RE_t)$			
Lag Order	(1 , 0 , 0 , 0, 1 , 1)			
Testing ARDL (F-stats)	5.2622**			
Testing ARDL (W-stats)	31.5732**			
	Table Values			
Level of Significance	F – Test		W – Test	
At 5%	3.0566	4.4795	18.3998	26.8769
At 10%	2.5336	3.7570	15.2017	22.5423
	DIAGNOSTIC TESTS			
Error's Correlation Test	2.6411 [0.104]		Error's Normal Distribution Test	0.3296 [0.890]
Model Specification Test	0.4436 [0.505]		Error's Variance Constancy Test	0.2332 [0.629]

Note: Double stars show 5% significance level and single star shows 10% significance level.
The information within brackets represents P.Values.

The optimal lag structure for the estimated model is specified as (1, 0, 0, 0, 1, 1), indicating the lag lengths for each variable in the model. The F-statistic and W-statistic are calculated to assess the significance of the estimated model. The results of the above table show that both statistics exceed their respective critical bounds at the 5% significance level, indicating a statistically significant relationship between the variables. The significance of the F-statistic shows that at least one coefficient in the model is statistically significant, while the W-statistic tests for the joint significance of all coefficients. The above table also depicts important diagnostic tests to evaluate the robustness of the estimated model. The results show that all major diagnostic tests do not reveal any significant issues, as indicated by the test statistics and their associated probability values. Therefore, based on these findings, we can conclude that the estimated ARDL model provides a reliable representation of the relationship between the variables, both in terms of long run association and diagnostic test for model validity. Table 5 has shown long-run coefficients for a specified dependent variable, along with their respective standard errors, t-statistics, and p-values. The coefficients of labor and capital are highly significant, suggesting a strong positive effect on Economic growth. For positive relationship see (Sani et al. 2018; Kala et al 2018; Ashiq et al., 2023; Audi et al., 2024; Tawari, 2024). The variable of export is also highly significant, indicating a robust increase economic growth of Singapore. Similarly, foreign direct investment and renewable energy are both highly significant, further indicating strong positive effects. The results of Iqbal et al. (2023) are in line with findings of this study. Overall, the table suggests multiple significant predictors of the dependent variable, with varying degrees of influence and statistical significance.

The table outlines the short-run coefficients for a specified dependent variable, including their standard errors, t-statistics, and p-values. A coefficient of labor is highly significant, indicating a strong positive short-run effect. The coefficient of capital is 0.6082, is marginally significant, suggesting a moderate positive influence. Another significant positive effect is observed with the coefficient of export i.e. 0.2268 showing a high significance. The coefficient 0.0774, with a smaller standard error of 0.0108, is very significant ($t = 7.1469$, $p = 0.0001$), implying a notable positive impact. In contrast, the coefficient of renewable energy is not significant ($t = 1.0013$, $p = 0.3263$), indicating a negligible short-run effect. Lastly, the coefficient of the error correction term CointEq(-1) is -0.6178, which is highly significant ($t = -6.2622$, $p = 0.0001$). This negative coefficient suggests a strong adjustment mechanism towards long-run equilibrium, implying that deviations from the long-run equilibrium are corrected by 61.78% in each period. Overall, the table indicates several significant short-run predictors, along with a robust error correction

term. The CUSUM and CUSUM Square plots provide visual and statistical checks for the stability of a model's coefficients and error variance, helping to ensure the reliability of the model over time.

Table 5: Results for Long Run

Variable on Left Hand Side = $\ln GDPPC_t$

Variables on Right Hand Side	Calculated Value	SE	t-test	P.Value
$\ln LAB_t$	0.6840	0.0610	11.2195	0.0000
$\ln CAP_t$	0.9845	0.5489	1.7936	0.0850
$\ln EXP_t$	0.3671	0.0871	4.2161	0.0003
$\ln FDI_t$	0.1578	0.0266	5.9328	0.0000
$\ln RE_t$	0.2664	0.0471	5.6582	0.0000
C	-0.1711	0.0749	-2.2853	0.0310

Table 6: Results for Long Run

Variable on Left Hand Side = $\Delta \ln GDPPC_t$

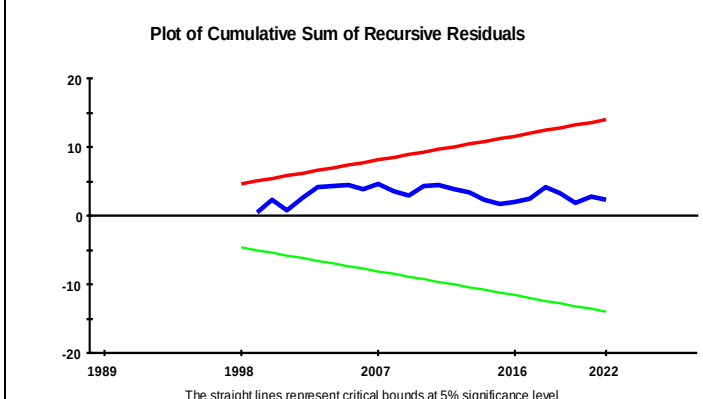
Variables on Right Hand Side	Calculated Value	SE	t-test	P.Value
$\Delta \ln LAB_t$	0.4226	0.0959	4.4079	0.0002
$\Delta \ln CAP_t$	0.6082	0.3094	1.9660	0.0605
$\Delta \ln EXP_t$	0.2268	0.0486	4.6698	0.0001
$\Delta \ln FDI_t$	0.0774	0.0108	7.1469	0.0000
$\Delta \ln RE_t$	0.0218	0.0217	1.0013	0.3263
CointEq(-1)	-0.6178	0.0987	-6.2622	0.0000

Diagnostic Tests

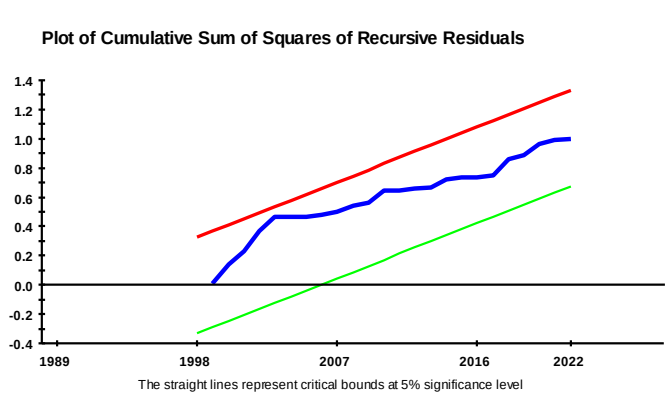
R Square after Adjustment	0.7453
F- Stats with P.Value	17.4275 (0.000)
Durbin's Test for Serial Correlation	2.4885
AIC	159.4432
SBC	152.5746

Figure 1: CUSUM and CUSUM Square

CUSUM



CUSUM Square



5. Conclusion and policy recommendations

The findings of this study support the pivotal role of renewable energy in strengthening Singapore's long-term economic growth, as evident by the significant and positive relationship identified using the ARDL approach within the Cobb-Douglas production framework. Although the short-term impact of renewable energy on economic growth appears negligible, the substantial long-term benefits advocate for sustained investment in renewable energy infrastructure. The results further highlight that both exports and FDI inflows enhance economic growth significantly in both time spans. The positive influence of foreign direct investment (FDI) inflows and exports underscores the need for policies fostering an open economy and facilitating international trade and investment. Additionally, we witness that labor force and capital accumulation consistently contribute positively to economic growth, highlighting the importance of enhancing workforce skills and capital investments for targeting domestic production. The significant and negative ECM's coefficient indicates a swift adjustment towards long-term equilibrium after short-term deviations. Based on these insights, policymakers should prioritize long-term strategies for expanding renewable energy, alongside initiatives to attract FDI inflows, enhance export competitiveness, and invest in human capital and physical infrastructure to sustain robust economic growth. The government should continue to provide incentives such as tax breaks, grants, and subsidies for renewable energy projects to encourage private sector investment. Develop and expand education and vocational training programs focused on renewable energy technologies and sustainable practices. Create financial mechanisms that make it easier for businesses to access capital for renewable energy projects, such as low interest loans and green bonds.

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