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THE NEXUS BETWEEN RENEWABLE ENERGY, ECONOMIC GROWTH, AND CARBON DIOXIDE EMISSIONS: EVIDENCE FROM MS-VAR AND MS-GRANGER CAUSALITY METHODS

Yenilenebilir Enerji, Ekonomik Büyüme ve Karbondioksit Emisyonları Arasındaki İlişki: MS-VAR ve MS-Granger Nedensellik Yöntemlerinden Kanıtlar

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Keywords: MS-VAR, MS-Granger Causality, Renewable Energy, Carbon Dioxide Emissions, Economic Growth, Regime Switching

JEL Codes: Q53, C32, Q42

Abstract

This study aims to examine the dynamic relationship between carbon dioxide (CO_2) emissions, renewable energy consumption, and economic growth in Denmark, Sweden, and Chile. These countries were not randomly selected. They were chosen since they have the highest scores according to the Climate Change Performance Index (2023). In addition, Markov-switching vector autoregressive (MS-VAR) and Markov-switching Granger (MS-Granger) causality methods are applied to the annual data of the three countries over the period 1971–2021. Contrary to linear methods, MS-VAR and MS-Granger causality approaches allow us to estimate and interpret this relationship for different regimes, such as recession and expansion. These methods also provide insights into the likelihood and duration of the persistence of the current economic regime. The empirical results show that there is a two-way MS-Granger causality between renewable energy consumption and economic growth in all regimes for the three countries except for moderate and high expansion regimes for Chile. Moreover, in general, there is a two-way MS-Granger causality between economic growth and CO_2 emissions in all regimes. Furthermore, the findings from the estimated models indicate that there is a two-way MS-Granger causality between renewable energy consumption and CO_2 emissions in general, except for the second regime for Chile.

Anahtar Kelimeler: MS-VAR, MS-Granger Nedensellik, Yenilenebilir Enerji, Karbondioksit Emisyonları, Ekonomik Büyüme, Rejim Değişimi

JEL Kodları: Q53, C32, Q42

Öz

Bu çalışma, Danimarka, İsveç ve Şili'deki CO_2 emisyonları, yenilenebilir enerji tüketimi ve ekonomik büyüme arasındaki dinamik ilişkiyi incelemeyi amaçlamaktadır. Bu ülkeler rastgele belirlenmemiştir. İklim Değişikliği Performans Endeksi'ne (2023) göre en yüksek puanlara sahip ilk üç ülke oldukları için seçilmişlerdir. Ayrıca, üç ülkenin 1971-2021 yılları arası yıllık verilerine Markov rejim değişimli vektör otoregresif (MS-VAR) ve Markov rejim değişimli Granger (MS-Granger) nedensellik yöntemleri uygulanmıştır. Doğrusal yöntemlerin aksine, MS-VAR ve MS-Granger nedensellik yaklaşımları bu ilişkiyi durgunluk ve genişleme gibi farklı rejimler için tahmin etmemize ve yorumlamamıza olanak sağlamaktadır. Bu yöntemler aynı zamanda ülke ekonomisinin mevcut rejimde kalma olasılığı ve süresi hakkında da bilgiler sağlamaktadır. Ampirik sonuçlar, Şili için ılımlı ve hızlı büyüme rejimleri hariç, üç ülke için de tüm rejimlerde yenilenebilir enerji tüketimi ile ekonomik büyüme arasında iki yönlü MS-Granger nedenselliği olduğunu göstermektedir. Ayrıca, genel olarak, tüm rejimlerde ekonomik büyüme ve CO_2 emisyonları arasında iki yönlü bir MS-Granger nedenselliği bulunmuştur. Son olarak, tahmin edilen modellerden elde edilen bulgular, Şili için ikinci rejim hariç, genel olarak yenilenebilir enerji tüketimi ile CO_2 emisyonları arasında iki yönlü bir MS-Granger nedenselliği olduğunu göstermektedir.

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1. Introduction

The rapid rise of the world's population, industrialization, and living standards, together with technological improvements, contribute to an increase in energy usage. To meet increased energy demand, fossil fuels such as coal and oil are widely preferred. The use of fossil fuels causes greenhouse gas emissions. CO_2 has the largest share of greenhouse gases. Greenhouse gases play a major role in the issue of climate change caused by global warming, as they cause heat to be trapped in the atmosphere. Fossil fuels account for about 81% of all primary energy resources globally. Oil has a share of 38.2% of these fossil fuels, coal 35.5%, and natural gas 26.3% (IEA, 2015). According to the European Commission Joint Research Center assessment, 90% of worldwide CO_2 emissions are caused by the use of fossil fuels (Olivier et al., 2012). Concerns about the environmental impacts of CO_2 emissions have shifted the global energy search to clean and renewable energy sources. Renewable energy provides an alternate energy source while also reducing the impacts of climate change. In addition, the use of renewable energy is one of the most reliable approaches to meeting long-term development goals such as social and economic development, energy availability and security, and environmental and health effects reduction (IEA, 2016; Lee, 2019; Chen et al., 2020).

Environmental degradation has become a priority in global forums due to the negative impact of increasing CO_2 emissions on the environment. Accordingly, the Kyoto Protocol was signed in 1997, and the Paris Climate Agreement was signed in 2015. The central authorities of each nation were urged or compelled to reassess their energy policy under this approach (Bhattacharya et al., 2016). Both the Kyoto Protocol and the Paris Climate Agreement aim to encourage signatory countries to decrease CO_2 emissions and use renewable energy to tackle environmental challenges (Nguyen and Kakinaka, 2019). Following the drop in energy demand caused by the pandemic (COVID-19) in 2020, global economic activity recovered in 2021, resulting in a 4% increase in global energy usage and record CO_2 emissions. Following the United Nations Climate Change Conference (COP26) in 2021, nations responsible for more than 80% of today's CO_2 emissions have committed to reducing greenhouse gas emissions and, in certain cases, attaining net-zero emissions. Furthermore, fluctuating fossil fuel costs, energy security, and nations' efforts to decarbonize have increased interest in renewable energy sources (IEA, 2022; REN21, 2022). Therefore, understanding the relationship between renewable energy consumption, CO_2 emissions, and economic growth is critical for revealing the economy's reliance on energy, achieving the targets of economic development and sustainability, and fighting climate change. In this regard, four distinct hypotheses have been tested in the literature to identify the direction of the link between economic growth and energy consumption (Apergis and Payne, 2010a; Ocal and Aslan, 2013; Shahbaz et al., 2015). The growth hypothesis suggests a one-way causal relationship between economic growth and energy consumption. This demonstrates that the economy is dependent on energy, and so energy-saving initiatives negatively affect economic growth. The conservation hypothesis asserts a one-way causal relationship from economic growth to energy consumption; therefore, energy-saving policies will not adversely affect economic growth. The feedback hypothesis states that there is a two-way causal relationship between variables. Finally, the neutrality hypothesis refers to the lack of a causal relationship between variables. This indicates that energy-saving policies will have no effect on economic growth.

Many researchers have explored the causal relationship between renewable energy consumption, economic growth, and CO_2 emissions in the literature. The studies, however, differ in terms of the countries studied, energy types, sample periods, econometric methodology, and outcomes. One of the most important points where these studies differ from each other is that while some of them analyze economic time series with linear models, others use nonlinear structures. However, the nonlinear nature of economic series should not be ignored due to shocks such as policy changes, economic crises, and energy crises. If the variables we used in our study include structural breakdowns or conjunctural fluctuations, using a fixed-parameter model during the sample period may produce misleading outcomes. To avoid the circumstances described above, it is more appropriate to examine the causal relationship between these variables using nonlinear models with changing parameters across the sample period.

In this paper, the MS-Granger causality method devised by Warne (2000) and Psaradakis et al. (2005) is applied to analyze the relationship between variables. This method is grounded in the view that the quantity and timing of changes in the causal relationship between the variables analyzed are stochastic and follow an unobservable Markov chain. In other words, contrary to standard VAR models, the parameters change over time. The MS-Granger causality approach was chosen because each economic regime has its own characteristics and provides regime-specific policy recommendations as well as important information about how the economy changes in different regimes. Traditional econometric methods suggest a common policy rather than a regime-specific policy (Fallahi, 2011).

This study aims to analyze the relationship between renewable energy consumption, economic growth, and CO_2 emissions for Denmark, Sweden, and Chile in 1971–2021 using the MS-VAR and MS-Granger causality methods. These countries are the top three with the best scores, according to the Climate Change Performance Index (CCPI) 2023 report. The CCPI assesses the 2030 objectives of nations in key areas, including greenhouse gas emissions, renewable energy, and energy, to see how close they are to the goal of below 2°C. Additionally, this index contains relative indicators that assess the present state and past trends in each of the three areas. In the calculation of the CCPI score, emission indicators account for 40%, renewable energy for 20%, and energy usage for 20%. The other 20% is composed of the climate policies of the related countries (CCPI, 2018). The CCPI appears to be an instrument designed to improve international climate policies' transparency. For this reason, it is a crucial scoring system to bring attention to the nations that implement the best climate policies (i.e., those with the highest CCPI ratings) and serve as an example for those that do not uphold their duties. Our study contributes to the literature in three ways. First, by applying the MS-VAR and MS-Granger causality methods, which offer policy suggestions that are particular to each regime by modeling the relationship between variables in separate regimes, our study introduces a novel analytical framework to this research area. These methods allow us to capture the dynamic and nonlinear relationships among the variables, which traditional linear models might overlook. The ability of MS-VAR to account for regime changes offers deeper insights into how these relationships evolve under different economic conditions. Second, we selected the top three countries in our research according to the CCPI, which is based on the weights of 14 metrics and four sub-indices. Thus, it is considered to provide valuable results that can inform policy decisions in other countries striving to improve their climate performance. Third, utilizing data spanning from 1971 to 2021, our study provides a comprehensive long-term analysis. This extensive temporal scope enables us to observe the structural changes and long-term trends in renewable energy consumption, CO_2 emissions, and economic growth, offering a robust understanding of their interplay over half a century. The research is designed as follows: An overview of the relevant literature is provided in the second section. The third section provides an explanation of the data and the methodology. The empirical results of the MS-Granger causality and the linear Granger causality methods are presented and interpreted in the fourth section. The fifth section is composed of economic discussions and policy implications for each country. The conclusion is presented in the final section.

2. Literature Review

The current literature on the relationship between renewable energy consumption, CO_2 emissions, and economic growth falls into three categories. In the first, the relationship between economic growth and CO_2 emissions is examined. The main theory used to investigate this relationship is the Environmental Kuznets Curve (EKC). Grossman and Krueger (1991) have revealed that there is an inverted-U-shaped relationship between income and environmental pollution. Numerous studies (such as Lindmark, 2002; Ozturk and Acaravci, 2010; Tiwari et al., 2013; Can and Gozgor, 2017; Yao et al., 2019; Chen et al., 2020) have confirmed the validity of the EKC hypothesis for the nations of the European Union. However, Mazur et al. (2015) argued that the EKC hypothesis is not valid for the whole EU region. Dinda (2004) reviewed various studies in the literature that studied the EKC hypothesis and concluded that there is no single policy that can reduce CO_2 emission levels while the economy grows. Shahbaz and Sinha (2019) also tested the validity of the EKC hypothesis for the period 1991–2017. They concluded that the hypothesis does not have a definite validity and that it varies depending on the time period studied, the explanatory variables used, and the empirical method employed.

The dynamic linkages between economic growth and renewable energy comprise the second section of this literature review. Apergis and Payne (2010b) looked at this relationship for 20 OECD countries. The authors found a two-way relationship between these variables in both the short and long runs using panel cointegration and causality tests. Al-Mulali et al. (2014) assessed 18 Latin American countries, while Salim and Rafiq (2012) examined six important rising economies; both studies found a two-way (feedback hypothesis) relationship between the variables. Sadorsky (2009) suggested that there is a conservation hypothesis between these two variables in emerging economies. Similarly, Ocal and Aslan (2013) reported the same findings for Turkey, as did Cho et al. (2015) for 31 OECD countries. Payne (2009), on the other hand, used the Toda-Yamamoto causality approach and obtained results supporting the neutrality hypothesis for the United States. Menegaki (2011) also found no significant relationship (neutrality hypothesis) between variables in his analysis of 27 European countries. Inglesi-Lotz (2016) found evidence for the growth hypothesis in 34 OECD countries, Fang (2011) in China, and Kula (2014) in 19 OECD countries. Kocak and Sarkgunesi (2017) investigated the same variables using a panel data analysis that included all nine Black Sea and Balkan countries and found a two-way relationship (feedback hypothesis).

The third and final section of the literature review focuses on the relationship between renewable energy, CO_2 emissions, and economic growth. Apergis et al. (2010) added the nuclear energy variable to these three variables in their research. They examined the causal relationship for 19 developed and emerging countries using the panel causality and panel error correction methods. Although the results of the analysis do not show that renewable energy reduces CO_2 emissions in the short run, there is a statistically significant positive relationship between them in the long run. Salim and Rafiq (2017) investigated the relationship between these three variables and oil prices in six important emerging countries, applying the panel Granger causality. The results of their study revealed that both CO_2 emissions and economic growth have a two-way causal relationship with renewable energy in the short run. Adewuyi and Awodumi (2017) studied these three variables for West African countries. They found a two-way relationship between renewable energy and CO_2 emissions in five West African countries and a partial relationship between three variables in the others. Dong et al. (2018) reviewed 128 countries across six major regional subgroups. Estimated results for European and Eurasian countries emphasize that there is a two-way causal relationship between CO_2 emissions and economic growth, while there is a one-way causal relationship from renewable energy to CO_2 emissions. Musah et al. (2020) used the Dumitrescu-Hurlin panel causality test for 16 West African countries. Across the panel, they found that there is a one-way causal relationship from renewable energy to economic growth (growth hypothesis), and both renewable energy and economic growth have a two-way causal relationship with CO_2 emissions. Also, Radmehr et al. (2021) analyzed European Union countries. Their findings demonstrate that economic growth has a two-way causal relationship with both CO_2 emissions and renewable energy.

3. Methodology and Data

3.1. Data

In our study, we included the top three countries (Denmark, Sweden, and Chile) with the highest scores according to the CCPI in the empirical analysis for factors such as data availability and common time periods between countries. The analyzed variable GDP represents GDP per capita (constant, 2015 US dollars), the variable REN represents renewable energy consumption (PJ), and the variable CO_2 represents CO_2 emissions (Mt CO_2). Yearly data covers the period 1971–2021. The GDP data was taken from the World Bank Development Indicators (WDI, 2023); CO_2 and REN data were gathered from the British Petroleum and International Energy Agency (IEA), respectively. In the study, all variables are subject to logarithmic transformation. The logarithmic GDP per capita, renewable energy consumption, and CO_2 emissions are denoted as LGDP, LREN, and LCO_2, respectively. Furthermore, the first differences are denoted as DLGDP, DLREN, and $DLCO_2$.

3.2. Methodology

3.2.1. MS-VAR Analysis

If the variables analyzed change their behavior over time, that is, across regimes, it would be incorrect to use vector autoregressive (VAR) models in the estimation. To investigate the relationship between these variables, MS-VAR models can be utilized (Fallahi, 2011). The studies of Goldfeld and Quandt (1973) have introduced the Markov-switching regression model to the literature on econometrics. Hamilton (1989) developed a Markov switching autoregressive (MS-AR) model. In Hamilton's MS-AR model, a single variable is utilized, and transitions between regimes have constant probability. Thus, Krolzig (1997) evolved the MS-VAR model, in which the VAR model's autoregressive parameters vary depending on the unobserved regime variable.

Krolzig (2003) defines the p th-order MS-VAR model as:

$$y_t = \mu(s_t) + A_1(s_t)y_{t-1} + \cdots + A_p(s_t)y_{t-p} + u_t \tag{1}$$

where, $\mu(.)$ represents the intercept coefficient in each regime, whereas $A(.)$ and Σ represent the variable's autoregressive coefficients in different regimes and the error term's variance, respectively. In the MS-VAR model, the unobserved regime variable (s_t) is generated by the Markov chain.

$$Pr\left(s_t \middle| \{s_{t-j}\}_{j=1}^{\infty}, \{y_{t-j}\}_{j=1}^{\infty}\right) = Pr(s_t|s_{t-1};\rho) \tag{2}$$

Here, ρ contains the probability parameters. That is, the regime at time t will depend only on the regime at time $t-1$. However, as seen in the equation $P(y_t|Y_{t-1}, s_{t-1}) = P(y_t|Y_{t-1})$, the conditional probability distribution of y_t is independent of s_{t-1}. Since the observable y_t series contains information about its situation, statistical inferences can be made about the unobservable s_t (Krolzig, 1998: 3).

$$Pr(s_t = j|s_{t-1} = i, s_{t-2} = k, \dots) = Pr(s_t = j|s_{t-1} = i) = p_{ij} \tag{3}$$

$$\sum_{j=1}^{M} p_{ij} = 1, \quad i, j \in \{1, \dots, M\} \tag{4}$$

Here, p_{ij} gives the probability of transition from state i to state j, and $0 \le p_{ij} \le 1$. The transition probabilities matrix is seen here (Hamilton, 1994: 679):

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1M} \\ \vdots & \ddots & \vdots \\ p_{M1} & \cdots & p_{MM} \end{bmatrix} \tag{5}$$

For the estimation of MS models, Hamilton (1989) suggested two methods: Maximum Likelihood (ML) and Expectation Maximization (EM). Dempster et al. (1977) developed the EM technique based on an iterative ML method due to the large number of parameters estimated in the MS-VAR model. The EM approach is intended to estimate the parameters of models in which observed time series are dependent on unobserved stochastic variables (Krolzig, 1997: 103).

3.2.2. MS-Granger Causality Analysis

Warne (2000) and Psaradakis et al. (2005) introduced the MS-Granger causality method to the literature for cases where causal relationships can change along the period of interest. This causality method is based on the MS-VAR model in which the parameters of the VAR model change over time. The time variation of the parameters of the model varies according to the existence and direction of causality. The MS-Granger causality method can be applied to MSIA(.)-VAR(.) and/or MSIAH(.)-VAR(.) models (Fallahi, 2011: 4168). By considering the estimated variables, the MS-VAR Granger causality approach can be described by using the following equation vector:

$$\begin{bmatrix} LGDP_t \\ LREN_t \\ LCO2_t \end{bmatrix} = \begin{bmatrix} \mu_{1,st} \\ \mu_{2,st} \\ \mu_{3,st} \end{bmatrix} + \sum_{k=1}^{q} \begin{bmatrix} A_{11}^{(k)} s_t & A_{12}^{(k)} s_t & A_{13}^{(k)} s_t \\ A_{21}^{(k)} s_t & A_{22}^{(k)} s_t & A_{23}^{(k)} s_t \\ A_{31}^{(k)} s_t & A_{32}^{(k)} s_t & A_{33}^{(k)} s_t \end{bmatrix} \begin{bmatrix} LGDP_{t-k} \\ LREN_{t-k} \\ LCO2_{t-k} \end{bmatrix} + \begin{bmatrix} e_t \\ \varepsilon_t \\ \xi_t \end{bmatrix} \quad (6)$$

The coefficients of the lagged values of LGDP, LREN, and LCO_2 for each variable can be used to assess the existence of a causal relationship between the variables. For the LGDP vector, it means that LREN is the cause of LGDP if any of the coefficients of the lagged values of LREN are significantly different from zero in any regime. It is same for the coefficients of the lagged values of LCO_2 in the LGDP vector. Testing the hypotheses $H_0 = A_{12}^{(k)} = 0$ and $H_0 = A_{21}^{(k)} = 0$; $H_0 = A_{13}^{(k)} = 0$ and $H_0 = A_{31}^{(k)} = 0$; $H_0 = A_{23}^{(k)} = 0$ and $H_0 = A_{32}^{(k)} = 0$ will determine MS-Granger causality (Psaradakis et al., 2005:6).

4. Empirical Results

The first step before doing causality tests is to determine the LGDP, LREN, and LCO_2 series integration levels. We used the ADF test proposed by Dickey and Fuller (1981) and the PP test proposed by Phillips and Perron (1988) for this purpose. Table 1 shows the results of unit root tests. Due to the results, there is a unit root at the level for these variables in all countries. However, the first differences of LGDP, LREN, and LCO_2 appear to be stationary. As a result, we can say that LGDP, LREN, and LCO_2 are integrated into order one, I(1).

Table 1. Results from Unit Root Tests

		Denmark	**Sweden**	**Chile**
LGDP	PP-stat	-1.4368	-2.6274	-2.9783
DLGDP		-5.9082***	-5.3575***	-5.0583***
LREN		1.5225	-2.5673	-1.2053
DLREN		-8.5061***	-8.5748***	-5.6090***
LCO_2		-0.9503	-3.1794	-2.2055
$DLCO_2$		-8.3924***	-7.6043***	-4.9906***
LGDP	ADF-stat	-1.3391	-2.6274	-3.2357
DLGDP		-5.9631***	-5.3575***	-5.0747***
LREN		-1.1208	-2.6016	-0.7012
DLREN		-11.4044***	-8.5748***	-5.5155***
LCO_2		-1.1141	-3.0787	-2.5013
$DLCO_2$		-8.2594***	-7.0648***	-4.9833***

Note: ***, ** and * denote 1%, 5% and 10% significant level.

The cointegration relationship between the variables is shown in Table 2. We used the maximum likelihood approach suggested by Johansen (1988, 1995). Based on these results, the null hypothesis is accepted. It means there is no cointegration, and the variables' innovations or first differences can be used for the MS-Granger causality approach.

Table 2. Results from Cointegration Test

Country	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Max-Eigen Statistic
Denmark	None	0.3706	30.1179	22.6921
	At most 1	0.0963	7.4257	4.9641
Sweden	None	0.3159	34.3831	18.6096
	At most 1	0.2455	15.7734	13.8029
Chile	None	0.2388	24.3459	13.3762
	At most 1	0.1524	10.9697	8.1028

Note: The critical values for trace statistic at 5% are 35.1927 and 20.2618 respectively. The critical values for max-eigen statistic at 5% are 22.2996 and 15.8921 respectively.

Following the likelihood ratio (LR) test approach proposed by Ang and Bekaert (1998) for regime-switching models, LR test statistics and Akaike information criterion (AIC) were used to test linearity and determine the number of regimes. Table 3 provides the LR test statistics. First, the linear VAR model was tested against the two-regime MS-VAR model and the null hypothesis was rejected at all significance levels for all countries. In other words, all the statistics support the existence of nonlinearity. Then, the LR test was applied again between the two-regime models and the three-regime model. According to the test results, the null hypothesis was rejected, and the three-regime MS-VAR model is appropriate for all countries. Regimes 1, 2, and 3 represent recession, moderate expansion, and high expansion, respectively. As a result, the MSIA(3)-VAR(4) model was selected for Denmark and Sweden, while the MSIA(3)-VAR(3) model was found to be the best model for Chile.

Table 3. LR Test Results

		Distribution	Statistics
Denmark	H_0: Linear VAR(4) H_1: MSIA(2)-VAR(4)	$\chi^2(41)$	139.0718
	H_0: MSIA(2)-VAR(4) H_1: MSIA(3)-VAR(4)	$\chi^2(45)$	279.9968
Sweden	H_0: Linear VAR(4) H_1: MSIA(2)-VAR(4)	$\chi^2(41)$	89.6602
	H_0: MSIA(2)-VAR(4) H_1: MSIA(3)-VAR(4)	$\chi^2(45)$	314.7942
Chile	H_0: Linear VAR(3) H_1: MSIA(2)-VAR(3)	$\chi^2(32)$	91.8032
	H_0: MSIA(2)-VAR(3) H_1: MSIA(3)-VAR(3)	$\chi^2(36)$	118.4912

Table 4 shows the estimated model findings for Denmark. The transition probabilities show that regime one has the highest persistency, with $p_{11} = 0.7265$. The average duration of this regime is 3.66 years. When the economy is in the moderate expansion phase, it has a higher possibility of switching to the high expansion phase than to the recession phase ($p_{21} = 0.1315$; $p_{23} = 0.2112$). This phase has a duration of 2.92 years on average, which is the shortest predicted. However, the probability of shifting to the recession regime is 12.75%, and to the moderate expansion regime is 19.13% when the economy is in the high expansion regime. In addition, according to the results of the diagnostic tests, the error terms of the model are normally distributed with constant variance at all significance levels and are also not autocorrelated at the 1% significance level.

Table 4. MSIA(3)-VAR(4) Model Estimation Results for Denmark

Variables	**Regime 1**			**Regime 2**			**Regime 3**		
	$DLCO_2$	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**
Intercept	-0.053***	0.003***	0.002	0.111***	0.002	-0.026	-0.065***	0.025***	0.084***
	(-3.542)	(2.651)	(0.226)	(3.519)	(0.809)	(-1.336)	(-4.561)	(21.466)	(9.702)
$DLCO_2$ (-1)	0.148	0.056***	0.239***	-0.337**	0.027**	-0.231***	-0.234**	-0.033***	-0.123**
	(1.389)	(6.556)	(3.707)	(-2.642)	(2.650)	(-2.985)	(-2.613)	(-4.610)	(-2.254)
$DLCO_2$ (-2)	-0.510**	-0.384***	0.413***	0.077	-0.029***	-0.269***	-0.352***	0.077***	0.896***
	(-2.630)	(-24.539)	(3.510)	(1.029)	(-4.757)	(-5.916)	(-2.747)	(7.496)	(11.541)
$DLCO_2$ (-3)	0.608***	0.052***	0.080	-0.981***	0.077***	-0.559***	0.847***	0.133***	-0.269***
	(4.199)	(4.424)	(0.906)	(-9.251)	(9.000)	(-8.691)	(8.304)	(16.197)	(-4.346)
$DLCO_2$ (-4)	0.378***	0.119***	0.550***	-0.625***	0.032**	-0.685***	-0.667***	0.011	0.166
	(2.796)	(10.897)	(6.702)	(-3.383)	(2.124)	(-6.105)	(-3.666)	(0.724)	(1.507)
DLGDP (-1)	1.024**	0.737***	0.341	-2.308*	0.586***	1.054	2.016***	0.088***	-1.034***
	(2.044)	(18.236)	(1.123)	(-1.770)	(5.576)	(1.332)	(5.403)	(2.936)	(-4.566)
DLGDP (-2)	0.938**	0.489***	0.146	2.973***	-0.077	-0.424	0.887***	0.092***	0.682***
	(2.307)	(14.917)	(0.592)	(4.279)	(-1.371)	(-1.006)	(2.741)	(3.536)	(3.475)
DLGDP (-3)	-1.771***	-0.986***	-0.489	-2.207***	0.101*	3.251***	-1.107***	0.340***	-0.127
	(-3.376)	(-23.331)	(-1.537)	(-3.377)	(1.925)	(8.197)	(-2.765)	(10.532)	(-0.521)
DLGDP (-4)	0.008	0.736***	-1.575***	-3.564***	0.161***	-1.152***	1.303***	0.337***	-0.660**
	(0.016)	(18.913)	(-5.377)	(-5.929)	(3.320)	(-3.159)	(2.871)	(9.213)	(-2.396)
DLREN (-1)	0.823***	0.404***	0.111	-1.254***	0.066***	-0.336***	0.027	-0.117***	1.383***
	(3.510)	(21.406)	(0.783)	(-9.782)	(6.426)	(-4.316)	(0.237)	(-12.826)	(20.149)
DLREN (-2)	-0.837***	-0.495***	-0.021	-0.021	-0.169***	-0.743***	-0.227	-0.124***	-0.896***
	(-4.254)	(-31.182)	(-0.176)	(-0.094)	(-9.285)	(-5.411)	(-1.376)	(-9.296)	(-8.942)
DLREN (-3)	1.568***	0.418***	0.465***	-0.107	0.149***	0.472**	0.145	0.162***	-0.141*
	(7.191)	(23.785)	(3.514)	(-0.335)	(5.796)	(2.442)	(1.220)	(16.848)	(-1.943)
DLREN (-4)	-0.899***	-0.368***	0.463***	0.579*	-0.061**	0.268	0.219***	0.017***	0.020
	(-5.107)	(-25.917)	(4.338)	(1.875)	(-2.432)	(1.430)	(7.103)	(6.86)	(1.082)
Standard error	0.020	0.002	0.012	0.020	0.002	0.012	0.020	0.002	0.012

	Transition Probabilities			**Duration**	**Diagnostic Tests**	
Regime 1	0.7265	0.1321	0.1414	3.66	Vector Portmanteau(9)	$\chi^2(45)$=61.9975 [0.0471]
Regime 2	0.1315	0.6573	0.2112	2.92	Vector Normality Test	$\chi^2(6)$=7.1445 [0.3077]
Regime 3	0.1275	0.1913	0.6811	3.14	Vector Hetero Test	$\chi^2(144)$=136.1158 [0.6678]
					Vector Hetero-X Test	$\chi^2(270)$=276.0000 [0.3878]

Note: ***, ** and * denote 1%, 5% and 10% significant level. In the part where the statistics of the diagnostic tests are given, the values in brackets denote p-values.

Table 5. MSIA(3)-VAR(4) Model Estimation Results for Sweden

Variables	Regime 1			Regime 2			Regime 3		
	$DLCO_2$	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**
Intercept	-0.068***	-0.004	0.020**	-0.036**	0.033***	0.056***	0.009	0.066***	0.002
	(-5.869)	(-0.950)	(2.617)	(-2.198)	(5.449)	(5.116)	(0.316)	(6.353)	(0.108)
$DLCO_2$ (-1)	-0.761***	-0.115***	0.377***	-0.297**	0.088*	-0.109	0.820**	-0.641***	0.460*
	(-7.296)	(-2.951)	(5.397)	(-2.287)	(1.808)	(-1.255)	(2.362)	(-4.944)	(1.978)
$DLCO_2$ (-2)	-0.141*	0.026	-0.066	-0.724***	0.113***	0.242***	0.403	-0.389***	0.576***
	(-1.739)	(0.857)	(-1.220)	(-9.640)	(4.043)	(4.812)	(1.249)	(-3.23)	(2.661)
$DLCO_2$ (-3)	-0.393***	0.082**	0.093	-0.044	0.059	-0.723***	0.087	0.480***	-0.317*
	(-4.339)	(2.430)	(1.535)	(-0.401)	(1.435)	(-9.832)	(0.318)	(4.723)	(-1.736)
$DLCO_2$ (-4)	0.078	0.054	-0.154**	-0.603***	0.027	0.063	-0.604***	0.314***	-0.494***
	(0.836)	(1.545)	(-2.461)	(-4.109)	(0.498)	(0.641)	(-2.898)	(4.038)	(-3.540)
DLGDP (-1)	-0.666*	0.886***	1.051***	-0.581*	-0.271**	0.346	-2.139***	-0.559***	1.272***
	(-1.996)	(7.121)	(4.702)	(-1.725)	(-2.155)	(1.531)	(-4.419)	(-3.093)	(3.920)
DLGDP (-2)	-0.402	-0.208**	-0.204	0.961**	0.318**	-1.385***	1.000	-2.310***	3.172***
	(-1.614)	(-2.232)	(-1.224)	(2.541)	(2.252)	(-5.464)	(0.684)	(-4.232)	(3.236)
DLGDP (-3)	-0.521	0.082	-0.301	-1.214***	-0.428***	-0.507**	-4.137***	1.568***	-1.337**
	(-1.377)	(0.584)	(-1.188)	(-3.383)	(-3.192)	(-2.107)	(-4.310)	(4.374)	(-2.079)
DLGDP (-4)	0.094	-0.226	0.282	0.964***	0.063	-1.674***	6.646***	-1.132***	1.099**
	(0.177)	(-1.147)	(0.796)	(3.140)	(0.547)	(-8.135)	(8.913)	(-4.065)	(2.200)
DLREN (-1)	-0.782***	-0.082	-0.087	-0.240*	-0.080	-0.336***	0.661***	0.120***	-0.316***
	(-3.427)	(-0.960)	(-0.566)	(-1.743)	(-1.555)	(-3.633)	(5.584)	(2.718)	(-3.987)
DLREN (-2)	0.637***	-0.149*	-0.418***	-0.027	-0.094**	-0.027	2.358***	0.047	-0.858***
	(3.150)	(-1.974)	(-3.087)	(-0.214)	(-2.001)	(-0.317)	(9.486)	(0.509)	(-5.150)
DLREN (-3)	-0.638***	-0.280***	0.592***	0.196**	0.016	-0.289***	0.745***	-0.343***	-0.202
	(-3.051)	(-3.581)	(4.222)	(2.097)	(0.447)	(-4.613)	(3.826)	(-4.719)	(-1.55)
DLREN (-4)	0.287**	0.016	-0.392***	-0.584***	0.043	0.148**	-1.956*	-1.070***	2.402***
	(2.485)	(0.365)	(-5.068)	(-6.579)	(1.295)	(2.491)	(-1.971)	(-2.886)	(3.611)
Standard error	0.017	0.006	0.011	0.017	0.006	0.011	0.017	0.006	0.011

	Transition Probabilities			Duration	Diagnostic Tests	
Regime 1	0.5890	0.1309	0.2801	2.43	Vector Portmanteau(9)	$\chi^2(45)$=50.6353 [0.2609]
Regime 2	0.1245	0.8091	0.0664	5.24	Vector Normality Test	$\chi^2(6)$ = 5.6369 [0.4651]
Regime 3	0.2742	0.1371	0.5887	2.43	Vector Hetero Test	$\chi^2(144)$ =119.3824 [0.9335]
					Vector Hetero-X Test	$\chi^2(270)$ =276.0000 [0.3878]

Note: ***, ** and * denote 1%, 5% and 10% significant level. In the part where the statistics of the diagnostic tests are given, the values in brackets denote p-values.

The estimated model for Sweden is MSIA(3)-VAR(4), and the analysis results are given in Table 5. According to the results, regime 2 represents the most persistent period with a duration of 5.24 years, and the probability of staying in this regime is quite high at 80.9%, as expected. The average duration of recession and high expansion regimes is identical at 2.43 years. However, the possibilities of staying in the same regime are almost equal, with 58.90% for the recession phase and 58.87% for the high expansion phase. For this country, when the economy is in one of the expansion regimes, it seems more likely to switch to the recessionary regime than switch to the other expansion regime. The probabilities of moving to the recessionary regime are $p_{21} = 0.1245$ and $p_{31} = 0.2742$. Finally, when the economy is in the recessionary phase, the probability of switching to the moderate expansion phase is 13.09%, while the probability of switching to the high expansion phase is 28.01%. Furthermore, diagnostic test findings demonstrate that the model's error terms have a normal distribution, a constant variance, and no autocorrelation.

The empirical findings for Chile are shown in Table 6. The MSIA(3)-VAR(3) model was selected as the best model for this country. The probabilities of staying in the same phase are $p_{11} = 0.6841$, $p_{22} = 0.5954$, and $p_{33} = 0.6427$. The average length of each regime corresponds with these findings. When the transition probabilities obtained for regime 1 are examined, it is seen that switching to regime 2 is more likely than switching to regime 3 ($p_{12} = 0.2370$; $p_{13} = 0.0789$). When the Chilean economy is in the high expansion phase, the probability of moving to the recessionary phase is highly low, with $p_{31} = 2.136e - 11$, while it is $p_{32} = 0.3573$ for moving to the moderate expansion phase. In addition, the possibility of shifting to the recessionary regime is 15.66%, and to the high expansion regime is 24.79% when the economy is in the moderate expansion regime. Additionally, the model's error terms have no autocorrelation, or constant variance, and are normally distributed, according to the findings of diagnostic tests.

Table 6. MSIA(3)-VAR(3) Model Estimation Results for Chile

Variables	Regime 1			Regime 2			Regime 3		
	$DLCO_2$	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**
Intercept	-0.018	-0.018**	-0.001	0.000	0.033***	0.026**	0.130***	0.093***	0.078***
	(-1.481)	(-2.360)	(-0.090)	(-0.010)	(3.798)	(2.236)	(4.270)	(4.802)	(3.082)
$DLCO_2$ (-1)	2.000***	2.390***	1.343***	-0.144	-0.068	-0.328**	0.424	0.330*	0.776***
	(4.864)	(9.171)	(3.905)	(-0.855)	(-0.639)	(-2.324)	(1.395)	(1.714)	(3.052)
$DLCO_2$ (-2)	0.880***	0.822***	0.619**	-0.283*	-0.271***	-0.037	-0.466**	-0.063	-0.135
	(2.774)	(4.089)	(2.332)	(-1.799)	(-2.724)	(-0.284)	(-2.035)	(-0.438)	(-0.707)
$DLCO_2$ (-3)	1.028***	1.377***	-0.141	0.351	0.084	0.291	0.366*	0.082	0.134
	(3.036)	(6.413)	(-0.499)	(1.665)	(0.626)	(1.651)	(1.910)	(0.677)	(0.833)
DLGDP (-1)	-1.758***	-1.761***	-1.239***	0.977**	0.356	0.424	-0.559	0.067	0.260
	(-4.943)	(-7.815)	(-4.167)	(2.428)	(1.395)	(1.259)	(-0.926)	(0.176)	(0.515)
DLGDP (-2)	-0.574*	-0.490**	-0.225	-0.241	0.071	-0.366*	1.811***	-0.518	-0.666
	(-1.783)	(-2.399)	(-0.836)	(-0.942)	(0.441)	(-1.711)	(3.336)	(-1.504)	(-1.466)
DLGDP (-3)	-0.064	-0.346**	0.399*	0.009	0.082	-0.006	-0.134	-0.882	-1.119
	(-0.234)	(-2.002)	(1.746)	(0.039)	(0.587)	(-0.031)	(-0.159)	(-1.647)	(-1.582)
DLREN (-1)	-1.701***	-1.737***	-0.975***	-0.135	0.253	0.055	0.309	-0.578	-0.901
	(-4.323)	(-6.964)	(-2.965)	(-0.462)	(1.361)	(0.224)	(0.420)	(-1.239)	(-1.463)
DLREN (-2)	-1.143***	-0.703***	-0.702**	0.453	-0.057	0.261	-1.248***	-0.221	0.304
	(-3.162)	(-3.067)	(-2.321)	(1.602)	(-0.317)	(1.103)	(-3.523)	(-0.984)	(1.025)
DLREN (-3)	0.116	-0.194	0.429	-0.382	-0.255	-0.230	-1.014	0.903**	0.809
	(0.339)	(-0.893)	(1.494)	(-1.479)	(-1.558)	(-1.061)	(-1.603)	(2.252)	(1.530)
Standard error	0.028	0.018	0.023	0.028	0.018	0.023	0.028	0.018	0.023

	Transation probabilities			**Duration**	**Diagnostic Tests**	
Regime 1	0.6841	0.2370	0.0789	3.17	Vector Portmanteau(9)	$\chi^2(36)$=41.6687 [0.2377]
Regime 2	0.1566	0.5954	0.2479	2.47	Vector Normality Test	$\chi^2(6)$ = 9.6520 [0.1401]
Regime 3	2.136e-11	0.3573	0.6427	2.80	Vector Hetero Test	$\chi^2(108)$ =65.1578 [0.9996]
					Vector Hetero-X Test	$\chi^2(276)$ =282.0000 [0.3890]

Note: ***, ** and * denote 1%, 5% and 10% significant level. In the part where the statistics of the diagnostic tests are given, the values in brackets denote p-values.

4.1. MS-VAR and MS-Granger Causality Results

Table 4 shows the analysis findings for the MSIA(3)-VAR(4) model, which was found to be statistically appropriate for Denmark. According to these findings, in the first equation, where $DLCO_2$ (i.e., CO_2 innovation) is the dependent variable, the coefficients of all estimated for DLREN and DLGDP are statistically significant, but for DLGDP(-4) in the first regime, DLREN(-1) in the third regime, and both DLREN(-2) and DLREN(-3) in the second and third regimes. In addition, in all regimes, it was found that economic growth and renewable energy consumption are Granger causes of CO_2. All $DLCO_2$ and DLREN coefficients except $DLCO_2$(-4) in regime three were found to be statistically significant in the equation where GDP innovation is the dependent variable. Hence, CO_2 emissions and renewable energy consumption are the Granger causes of economic growth in all regimes. According to the third equation, where REN innovation is the dependent variable, all $DLCO_2$ coefficients are significant at conventional levels of significance, but $DLCO_2$(-3) in regime one and $DLCO_2$(-4) in regime three. When the estimated coefficients for DLGDP are considered, it can be seen from the results that DLGDP(-4) in regime one and DLGDP(-3) and DLGDP(-4) in regime two are statistically different from zero. Moreover, the only coefficient that is not statistically significant in regime three is DLGDP(-3). As a result, there is evidence of two-way Granger causality between renewable energy consumption and CO_2 emissions. Furthermore, it seems that economic growth is Granger cause of CO_2 emissions, while CO_2 is Granger cause of economic growth in the reverse direction. Additionally, results suggest evidence that there is two-way Granger causality between GDP and REN. It should also be noted that all Granger causality interpretations are valid for all regimes.

The MSIA(3)-VAR(4) model was chosen for Sweden, and Table 5 shows the results. When the GDP coefficients in the first model are examined, where $DLCO_2$ is the dependent variable, it seems to be that DLGDP(-1) in regime one, all in regime two, and all except DLGDP(-2) in regime three are statistically significant. Except for DLREN(-2) in the second regime, the REN coefficients of innovations are statistically different from zero in all regimes. When the significant coefficients of this equation are considered, we can say that economic growth innovations and renewable energy consumption innovations are the Granger causes of CO_2 emissions. All $DLCO_2$ coefficients in the DLGDP equation are significantly different from zero except $DLCO_2$(-2) and $DLCO_2$(-4) in regime one, $DLCO_2$(-3), and $DLCO_2$(-4) in regime two. Meanwhile, DLREN(-2) and DLREN(-3) in the first regime, DLREN(-2) in the second regime, and all DLREN coefficients in the third regime are also statistically significant. According to the results of this country, CO_2 and REN are Granger causes of GDP. Except for $DLCO_2$(-2) and $DLCO_2$(-3) in regime one and for $DLCO_2$(-1) and $DLCO_2$(-4) in regime two, all CO_2 innovations for DLREN are significantly different from zero in the third equation. On the other hand, DLGDP(-1) in regime one and all DLGDP coefficients except DLGDP(-1) in the second regime are statistically significant in the second and third regimes. Finally, as in Denmark, the findings of the study point out two-way Granger causality in all regimes between economic growth and renewable energy consumption, as well as between renewable energy consumption and CO_2 emissions and between economic growth and CO_2 emissions.

The best model for Chile was determined to be the MSIA(3)-VAR(3) model, as seen in Table 6. The coefficients of DLGDP(-1) and DLGDP(-2) in regime one, DLGDP(-1) in regime two, and DLGDP(-2) in regime three are significantly different from zero in the first model, where CO_2 innovation is the dependent variable. This means that there is Granger causality from GDP to CO_2. Also, the coefficients of DLREN(-1) and DLREN(-2) in regime one and DLREN(-2) in regime three are statistically significant. Hence, we may claim that Granger causality exists from REN to CO_2. But also, there is no evidence of a causal relationship between REN and CO_2 when the Chilean economy is in the moderate expansion regime. The second equation is the model, where gdp is the explained variable. All coefficients of CO_2 innovations in the first regime, $DLCO_2(-2)$ in the second regime, and $DLCO_2(-1)$ in the third regime are significantly different from zero. In the same equation, the coefficients of DLREN(-1) and DLREN(-2) in regime one and DLREN(-3) in regime three are statistically significant, while there is no Granger causality from REN to GDP in regime two. Additionally, in the third equation, the explained variable of which is REN innovation, $DLCO_2$ coefficients are statistically different from zero except $DLCO_2(-3)$ in regime one, $DLCO_2(-2)$ and $DLCO_2(-3)$ in both regimes two and three. Also, the coefficients of DLGDP(-1) and DLGDP(-3) in regime one and DLGDP(-2) in regime two are statistically significant, but there is also no Granger causality from GDP to REN. As a result, the findings show two-way Granger causality between economic growth and CO_2 emissions in all regimes, renewable energy consumption and CO_2 emissions in the first and third regimes, and one-way Granger causality from CO_2 emissions to renewable energy consumption in the moderate expansion regime. Consequently, for this country, it can be said that there is two-way Granger causality in the first regime, one-way Granger causality from GDP to REN in the second regime, and one-way Granger causality from REN to GDP in the third regime when the causal relationship between renewable energy and economic growth is considered.

4.2. Standard Linear Granger Causality Results

This section compares the causality obtained by two alternative approaches. The knowledge of the direction of causality is critically important for accurately determining the energy hypothesis and hence energy policy strategies. Therefore, we also applied the standard Granger causality method to the same data set and presented the results in Table 7. Our purpose is to compare the test results with the findings of the MS-Granger causality. When we examined the findings, we found that the results of the two tests completely contradicted each other. According to the results of the standard Granger causality method, there is no causality between renewable energy consumption and economic growth in any regime. It means the neutrality hypothesis holds for all three countries analyzed. In contrast to the results of the MS-Granger causality approach, we did not find evidence of the causality between CO_2 emissions and economic growth for any of the countries we studied when we applied the standard Granger causality method. In conclusion, MS-Granger findings differ greatly from standard Granger results because, while the first technique takes structural breaks or cyclical variations into account, the second one does not.

Table 7. Standard Linear Granger Causality Results

Countries	Causality Direction	χ^2	Prob.	Causality Decision
Denmark	DLGDP→$DLCO_2$	1.6996	0.4275	No
	DLREN→$DLCO_2$	2.1650	0.3387	No
	$DLCO_2$→DLGDP	1.9715	0.3732	No
	DLREN→DLGDP	3.3874	0.1838	No
	$DLCO_2$→DLREN	0.1952	0.9070	No
	DLGDP→DLREN	0.2829	0.8681	No
Sweden	DLGDP→$DLCO_2$	1.8978	0.1683	No
	DLREN→$DLCO_2$	0.8585	0.3541	No
	$DLCO_2$→DLGDP	0.1876	0.6649	No
	DLREN→DLGDP	0.2603	0.6099	No
	$DLCO_2$→DLREN	0.3629	0.5469	No
	DLGDP→DLREN	0.0298	0.8629	No
Chile	DLGDP→$DLCO_2$	0.0006	0.9802	No
	DLREN→$DLCO_2$	0.3742	0.5407	No
	$DLCO_2$→DLGDP	0.1551	0.6937	No
	DLREN→DLGDP	0.5493	0.4586	No
	$DLCO_2$→DLREN	0.2605	0.6098	No
	DLGDP→DLREN	0.0777	0.7803	No

5. Discussions and Policy Recommendations

In this section, we will discuss the empirical results of the MS-Granger causality method developed by Psaradakis et al. (2005). We found a two-way causal relationship between economic growth and CO_2 emissions for all three countries in all three regimes, which is consistent with Saidi and Omri (2020) and Radmehr et al. (2021) in Denmark and Sweden. Furthermore, there is evidence for a two-way causal relationship between renewable energy consumption and CO_2 emissions in all three regimes for all three countries but a one-way causal relationship from CO_2 to REN in the moderate expansion regime for Chile. These results comply with the results of Irandoust (2016) in Sweden. When the causality between economic growth and renewable energy consumption is considered, the results of our study show that there is evidence of a two-way causality between renewable energy consumption and economic growth in the recessionary regime for Chile and in all three regimes for Denmark and Sweden. Also, there is a one-way causal relationship from economic growth to renewable energy consumption in the moderate expansion regime and from REN to GDP in the high expansion regime for Chile. These conclusions are consistent with the results of Saidi and Mbarek (2016) in Sweden, Jebli et al. (2020) for Sweden and Denmark in the long run and for Chile in the short run, and Radmehr et al. (2021) in Denmark and Sweden. According to these findings, we concluded that the feedback hypothesis is valid in the recessionary regime, the conservation hypothesis in the moderate expansion regime, and the growth hypothesis in the high expansion regime for Chile, which is consistent with Joo et al. (2015) in Chile, while the feedback hypothesis is valid in all regimes for Denmark and Sweden.

According to the results for Denmark, there is a two-way causal relationship between CO_2 emissions and economic growth during times of recession. Based on IEA data, the fact that fossil fuels accounted for the majority of total energy usage for the years included in the analysis further supports this conclusion. At the same time, we found a two-way causal relationship between renewable energy consumption and CO_2 emissions. In addition, for both the moderate expansion and high expansion regimes, CO_2 emissions and renewable energy consumption cause economic growth, such as during times of recession. These results show that the feedback hypothesis is valid in all regimes for Denmark. However, the Danish government announced a net-zero by 2045 plan in 2022, with the goal of reducing emissions by 110% by 2050. In contrast to the MS-Granger causality findings, standard Granger causality results for Denmark suggest no relationship between economic growth and renewable energy consumption. Both causality approaches have completely different policy consequences, but the MS-Granger causality method is more reliable than the standard Granger causality because it takes into account the dynamics of the economy. Consequently, in order to reach its goals, the government should put in place incentive programs that encourage the use of renewable energy sources while keeping current regulations.

Sweden has the lowest CO_2 emissions, with 3.304 metric tons per capita in 2021. Also, according to the IEA (2019) report, the transport sector, which is still primarily reliant on oil, is the main source of greenhouse gas emissions. From 2010 to 2030, the government has set a goal to cut transportation-related emissions by 70%. They also intend to decrease carbon emissions by 59% in 2030 compared to 2005 and to have a net-zero carbon economy in 2045. The results obtained for Sweden show that there is a two-way causal relationship between CO_2 emissions and economic growth in all regimes. At the same time, we found a two-way causal relationship between renewable energy consumption and economic growth in the Swedish economy, while standard Granger causality results suggest that there is no relationship between them. For Sweden, the feedback hypothesis holds in all regimes, as in Denmark. These results emphasize the importance of sustainable energy policies in balancing economic development with environmental concerns. Thus, Swedish policymakers should focus on developing policies that promote the use of clean fuels in the transport sector.

In Chile, there is a two-way causal relationship between economic growth and CO_2 emissions in all regimes. CO_2 emissions have increased significantly as a result of rapid industrialization and increasing energy demand. According to the IEA (2018) report, the percentage of fossil energy sources in overall energy usage was 73.2% in 2016, which confirms these findings. This situation is also reflected in the level of the country's CO_2 emissions. Also, there is no two-way causal relationship between renewable energy and CO_2 emissions in the moderate expansion regime. Thus, increasing the share of renewable energy could reduce the value of CO_2 emissions. Furthermore, in the same regime, we found a one-way causal relationship from economic growth to renewable energy consumption, while this causality for the other direction exists in the high expansion regime. Despite the fact that standard Granger causality results support the neutrality hypothesis, MS-Granger findings suggest the conservation hypothesis and growth hypothesis in the moderate expansion regime and the high expansion regime, respectively. The Chilean government, which has committed to achieving net-zero emissions by 2050, has put in place a variety of policies and laws to encourage the production and use of renewable energy. Also, we recommend expanding incentives for renewable energy production and consumption, as well as investing in research and development to further improve renewable energy technologies.

Consequently, in the case of Denmark and Sweden, the feedback hypothesis, which holds in all three regimes, suggests that both countries have aligned environmental sustainability with economic growth. For these countries, we recommend that they keep investing more in renewable energy and promote technological innovation. For Chile, the different causal relationships between the regimes suggest that the Chilean government should regulate its energy policies in a flexible manner. During a recessionary regime, the validity of the feedback hypothesis implies that economic recovery requires increased investment in clean energy. Policymakers should invest in renewable energy infrastructure and provide incentives for both businesses and households to adopt renewable energy sources. In the moderate expansion regime, there is a one-way relationship from economic growth to renewable energy consumption. This finding may indicate that policymakers have not invested enough in renewable energy infrastructure while supporting economic growth or that these investments have been insufficient in the presence of economic growth. Therefore, we can say that during this regime, subsidies, tax incentives, and grants should be made more pronounced both to increase renewable energy investments and to incentivize renewable energy. The finding that renewable energy investments contribute to growth in the high expansion regime suggests that the development of renewable energy technologies and infrastructure is critical for sustainable economic growth in this regime. Besides this, given the two-way MS-Granger causality between economic growth and CO_2 emissions in all regimes, it is essential to develop strategies for sustainable economic growth that prioritize low-carbon development. Investing in green technologies, enhancing public transportation systems, and encouraging sustainable agricultural practices can help reach this goal. Finally, the two-way MS-Granger causality between renewable energy consumption and CO_2 emissions suggests that increasing renewable energy usage can directly reduce carbon emissions. Policies should therefore focus on scaling up renewable energy production and facilitating its adoption.

6. Conclusion

This study analyzes the relationship between CO_2 emissions, renewable energy consumption, and economic growth in different economic regimes for Denmark, Sweden, and Chile, the countries with the highest scores according to the CCPI (2023). For this purpose, MS-VAR and MS-Granger causality methods were applied to annual data for the period of 1971 to 2021. The MS-VAR and the MS-Granger causality approaches provide us the opportunity to estimate and interpret separately for different regimes of the economy, such as recession and expansion. In reality, the recession and expansion regimes of the economy have their own specific structure. These nonlinear methods are superior to linear ones because nonlinear methods take into account these specific structures of the economy. However, this is the first study that examines the relationships between the variables mentioned above by using MS-VAR and MS-Granger causality approaches. So it enriches the literature in this respect.

The results of this study show that there is a two-way causality between CO_2 emissions and economic growth in all regimes and for all countries. As expected, we found that CO_2 emissions were the cause of economic growth. This finding can be associated with the validity of the EKC hypothesis, which suggests that environmental pollution increases in the early phases of economic growth but decreases after a certain level of prosperity is reached as environmental awareness increases and cleaner technologies are adopted. Also, due to the findings, there is a two-way MS-Granger causality between renewable energy consumption and CO_2 emissions in general, except in the moderate expansion regime for Chile. The existence of this relationship in Denmark and Sweden, across all three regimes, indicates that these countries' energy policies promote the shift towards renewable energy. This result also supports sustainable growth theory while means that green economy transition strategies are effectively utilized. Additionally, when the relationship between renewable energy and economic growth is considered, our findings point to two-way causality for Denmark and Sweden. This implies that renewable energy investments are both a consequence and a propulsion of growth. This is consistent with long-term sustainable development goals, showing that growth increases energy demand, while energy efficiency and technology improvements contribute to economic growth. In all regimes for the three countries except moderate and high expansion regimes for Chile, the results support the feedback hypothesis that renewable energy and economic growth in general play a complementary role. However, for Chile, we also found evidence for the conservation hypothesis in the moderate expansion regime and for the growth hypothesis that renewable energy is the cause of economic growth in the high expansion regime. Standard Granger causality results assert neutrality between these variables. This means that an increase in GDP is not related to renewable energy use, and policy changes linked to renewable energy consumption will have no effect on economic growth. This is completely in contrast to the findings of the MS-Granger method. Given the fact that business cycles characterize economies, the development and implementation of regime-specific policies are critical for the proper management of resources. Therefore, if policymakers follow the findings of the standard causality tests, policies to be implemented could negatively impact the economy and the environment.

Consequently, all three countries attach great importance to the share of renewable energy sources and the reduction of CO_2 emissions, as evidenced by their high scores in the CCPI (2023) report. However, renewable energy consumption has a two-way causal relationship with both economic growth and CO_2 emissions in some regimes, while there is a one-way causal relationship in others, according to the research. Therefore, determining the existence and direction of the causal relationship between renewable energy and other variables separately for each regime is critical for developing accurate and effective environmental policies, taking into account the economic regime in which the country is located. In this respect, increasing investment in renewable energy technologies that do not cause climate change and environmental degradation, considering the transition phases between economic regimes, is a necessity for all countries to create a cleaner, healthier environment for current and future generations.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The first author of the study contributed to the conceptualization, methodology, data curation, writing-original draft preparation, and formal analysis of the research; the second and corresponding author of the study contributed to the conceptualization, reviewing of literature, writing-review and editing, visualization, and design of the discussion and results sections.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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