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The Relationship between Energy Consumption and Economic Growth in the Baltic Countries' Agriculture: A Non-Linear Framework

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Abstract: The development of a country's economy is directly related to the use of energy in that country's economic sectors. Therefore, the energy–environmental Kuznets curve (EEKC) is often used when analysing a country's potential and challenges in sustainable development, green economy, and green growth. This hypothesis tests whether there is an inverse "U"-shaped relationship between energy use and economic growth and is especially important when analysing developing countries to assess if, at a certain point, energy use begins to drop, resulting in fewer greenhouse gas emissions, environmental degradation, and the consumption of fossil-based fuels. This study aims to examine the relationship between energy consumption and economic growth in the Baltic States from 1995 to 2019, with a focus on the agriculture sector. The study uses the non-linear autoregressive distributed lag (NARDL) model for individual and panel time series. Total energy use, as well as electricity use, is included in the study, whereas gross value added is employed as a measure of economic growth. Research data analysis reveals that energy use in all three Baltic countries stabilises as gross value added increases. However, there is insufficient evidence to show that after a certain point, energy use begins to drop; thus, the hypothesis for the inverse "U"-shaped energy–environmental Kuznets curve (EEKC) is rejected. Research results have important practical implications regarding countries' policies toward energy, including the use of electricity and sustainable development.

Keywords: agricultural development; gross value added; energy use; NARDL model; energy–environmental Kuznets curve

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1. Introduction

In recent decades, climate change has become a global phenomenon, and its effects are becoming more and more evident. It threatens the environment, biodiversity, economic activity, and sustainable development. In addition, economic development has a significant impact on climate change and sustainable development [1]. It is recognised that sustainable environmental quality must be an essential part of sustainable economic development [2]. Scientists often associate better environmental quality with the reduction of greenhouse gas emissions, especially carbon dioxide (CO_2) emissions [3–6]. However, the development of economic activity is often associated with environmental degradation [7], and thus with negative effects on the climate. The world's largest amount of GHG emissions is produced by energy production: 87% of total GHG (2020) [8]. This problem must be solved primarily by improving energy use efficiency [9,10], developing and implementing clean production technologies, and increasing natural GHG absorbers [9]. It is characteristic of the economy as a whole and its individual sectors, including agriculture.

Energy resources are essential both for households to meet their personal needs and economic activities in the production of goods and services. Energy is used in many sectors:

industry (production of iron, steel, fertilisers, pharmaceuticals, production of food products and tobacco products, non-ferrous metals, paper, textiles, machinery and equipment, extraction of oil and gas and so on), transport (burning gasoline and diesel for all types of road transport, aviation, shipping, the railway sector, fuel and raw material transportation by pipelines, among others), residential and commercial buildings, agriculture, forestry, fishing, and the like. The production of heat and electricity emits the most GHG in the world [11]. In 2019, emissions from this sector amounted to 15.83 billion metric tonnes [12]. It is predicted that world energy-related CO_2 emissions will increase to 43.2 billion metric tonnes in 2040 [13]. The main driver of these pollutants is the increasing demand for energy, mainly obtained by burning fossil fuels [14,15].

Economic expansion and energy consumption have an interactive and complementary relationship [4]. In order to reduce the amount of GHG emissions and at the same time the negative impact on the climate, energy efficiency is essential. Energy efficiency is usually evaluated in terms of energy intensity [16,17], which shows the energy consumption to perform a specific process or produce a product in a country. It is a way to measure the relationship between energy consumption and economic growth [18]. The energy efficiency policy aims to produce more with less energy.

Although energy is the driver of the economy, it can lead to the deterioration of the quality of the environment [19]. Therefore, the economy must develop with less energy consumption. In other words, it is important to decouple economic growth from energy consumption when increasing energy efficiency. As energy efficiency increases, more benefits are obtained: GHG emissions, air, water, and soil pollution would be reduced; fewer resources would be used to extract, transform, transport, and use energy; as well as additional benefits related to the state of ecosystems [20].

As part of the European Green Deal, the EU has increased its ambitions in the field of increasing energy efficiency and aims to reduce primary and final energy consumption by at least 32.5% by 2030 at the EU level (compared with the energy consumption forecasts for 2030) [10]. Eurostat data also show that the decoupling of economic growth and energy consumption is increasing due to the EU's comprehensive energy efficiency policy [20,21]. Economic growth is one of the main goals of every country. It relates to energy use, and the latter to environmental impact. The interaction between energy consumption, economic growth, and environmental quality is rather controversial. Policy makers, therefore, face a significant challenge in balancing the goals of economic growth, energy use, and environmental impact. If energy is used inefficiently, the negative consequences for the economy are huge [22]. Therefore, countries are looking for ways to achieve sustainable development while reducing fossil fuel energy consumption and achieving economic growth [23].

The energy–environmental Kuznets curve (EEKC) can be used to determine the relationship between energy use and economic growth. The theory explains that an increase in energy consumption is accompanied by economic growth in the early stages of economic development, and after a tipping point in the later stages of economic development, energy consumption decreases as energy efficiency increases [24]. EEKC hypothesises that there are inverted U-shaped or N-shaped relationships between energy use and economic growth and development [25].

Conducted studies show that scientists and researchers often examine the relationship between environmental pollution (measured by GHG emissions) and economic growth and test the environmental Kuznets curve (EKC) hypothesis [26–30]. Since, as already mentioned earlier, the majority of GHG emissions are related to energy consumption, the research examines the relationship between energy consumption and economic growth and its directionality, and recent research expands and tests the energy–environmental Kuznets curve (EEKC) hypothesis.

It must be stated that EKC and EEKC are characterised by certain limitations and are criticised for both methodological and theoretical reasons: (i) EKC is based on the assumption that economic development directly leads to environmental degradation, different sources of pollution are used to assess it, there is no apparent interaction between pollution reduction demand and supply of instruments [31]; (ii) the unclear interaction between economic development and pollution levels taking into account the country's social system and national context [32]; (iii) with increasing technological progress and energy efficiency, energy costs may not only decrease, but may even increase [33,34]. Cheaper energy costs due to an increase in its use efficiency can encourage its consumption, which could increase the negative impact on the environment and climate change; this is referred to as Jevons' paradox [35]. This problem is highly relevant in agriculture since increased energy efficiency would result in increased agricultural production volumes and thus accelerate processes related to soil erosion, deforestation, and so on [36]. Thus, EEKC hypothesises that there are inverted U-shaped or N-shaped relationships between energy use and economic development [25]. Despite the shortcomings mentioned above and its limitations, the EEKC hypothesis is suitable for analysing the connections between energy use, economic growth, and environmental quality. It is often applied in this kind of research and can be regarded as a classic model [3] to analyse the interrelationships between economic development and energy use.

If Grossman and Krueger (1991, 1995) [37,38], Beckerman (1992) [39], and Panayotou (1993) [40] were the first to pay attention to the interrelationship between economic growth and environmental quality and present research results in 1991–1993, then the links between energy use and economic growth were empirically studied for the first time by Kraft J. and Kraft A. in 1978 [41]. They found a causal relationship between energy consumption and economic growth in the U.S. [42]. Although EEKC hypotheses have not been extensively studied they are receiving increasing attention in the last decade. The increasing number of scientists and researchers are studying this in various countries and regions (Ethiopia, Ghana, China, Egypt, 10 Asian countries, 19 Asia-Pacific countries, 22 Latin American and Caribbean countries, G7 countries) [22,23,43–48]. Research has revealed that there is no consensus on the direction of causality between energy use and economic growth [24]. Some studies argue for unidirectional causality that energy consumption determines economic growth [49,50] while others show unidirectional causality that economic growth determines energy consumption [45,51–53]. Still other studies have revealed a two-way causal relationship between energy consumption and economic growth [46,54,55], while others, on the contrary, state that there is no mutual relationship between these quantities [43,56,57]. To determine these interrelationships, researchers often use the Granger causality test method.

The inconsistencies of studies supporting the EEKC hypothesis and the relationship between energy use and economic growth often depend on the methods used by researchers. Non-parametric econometric methods are more suitable for determining the relationship mentioned above [58,59]. These methods do not require researchers to make many prior assumptions. In any case, understanding the causal relationship between energy use and economic development is vital in order to design and implement effective energy and environmental policies [42].

This study is, as far as it is known, the first to examine the relationship between energy use and economic growth in the Baltic States, i.e., in Estonian, Latvian, and Lithuanian agriculture, as well as check the energy–environmental Kuznets curve hypothesis using ARDL or NARDL modelling. It is also unique in that we compare energy use to electricity use and their relationships with economic growth.

The purpose of this study is to assess the relationship between economic growth and energy consumption in agriculture in the Baltic countries (Estonia, Latvia, and Lithuania). The Baltic countries (Estonia, Latvia, and Lithuania) are politically and economically similar. From 1940 to the restoration of independence in 1990–1991, they were annexed by the USSR in 2004 and became EU members. The agricultural structure of these countries [60] and the natural and climatic conditions for agricultural growth are similar. The study used ARDL/NARDL modelling to determine the relationship between energy use, including electricity use, and gross value added as an indicator reflecting economic growth in agriculture from 1995 to 2019. The authors outline their research strategies and the data they used in Section 2. The findings of the empirical research are presented in Section 3. The discussion and conclusions presented in this paper's last sections are based on an examination of the scientific literature and empirical research.

2. Materials and Methods

2.1. Data

The research investigates the hypothesis of the energy–environmental Kuznets curve (EEKC) in the Baltic nations' agricultural industry. The research employs a number of energy consumption indicators as a proxy for climate change, pollution, and environmental degradation. It is electricity use (LU) and total energy use (NU) in agriculture that result from economic growth as measured by agriculture's gross added value (GV). The research examines annual statistics from 1995 to 2019. The indicator of economic growth is gross value added. Eurostat databases are used to gather data on financial accounts. To compare the economic outcomes of various nations, the gross value added is analysed in purchasing power parities (PPP) at the current prices for each year. Food and Agriculture Organization (FAO) reports are used to gather data on energy use. The data in the database consists of agriculture, forestry, and fisheries (hereafter, it is referred to as agriculture). The data on energy use are given in terajoules.

2.2. Methods

The research tests the energy–environmental Kuznets curve (EEKC) hypothesis in the agriculture sector in the Baltic States.

The study analyses energy consumption as a factor affecting the development of the country's economy as well as directly determining the quality of the environment. This variable is used to assess whether, at a certain point, energy consumption begins to decrease as gross value added increases. Slowing down or reducing energy consumption results in lower GHG emissions, which in turn slows down environmental degradation. The study focuses on the agricultural sector, and FAOSTAT provides sufficiently detailed data on energy consumption in this sector, disaggregated by energy sources (fossil fuels, electricity among others.). It made it possible to study the impact of two dependent variables (total energy consumption and consumption of electricity as a less polluting environmental source) on the quality of the environment and compare the obtained results. Since economic growth can be both a positive and a negative indicator and does not indicate the level of development at which energy consumption would slow down or start to decrease, the study chose the independent variable, the gross added value created in agriculture, to describe economic growth. It reflects both the income of the population employed in the sector and the applied technologies, so it can be used to model the impact of gross added value on the volume of energy use and its efficiency.

The research is divided into several steps: (1) all three states' descriptive data for indicators are given and discussed; (2) the following time series data evaluation tests are run: Engle-Granger co-integration test; ADF test; (3) preliminary ARDL/NARDL modelling is performed to determine the best amount of time lag and whether there are any asymmetric relationships between energy use and gross value added; (4) final parameter values are estimated and research hypotheses are tested by selecting either ARDL or NARDL and adding dummy variables to test for structural breaks (if parameters of regression models change over time). Next, we provide the study's research framework (see Figure 1).

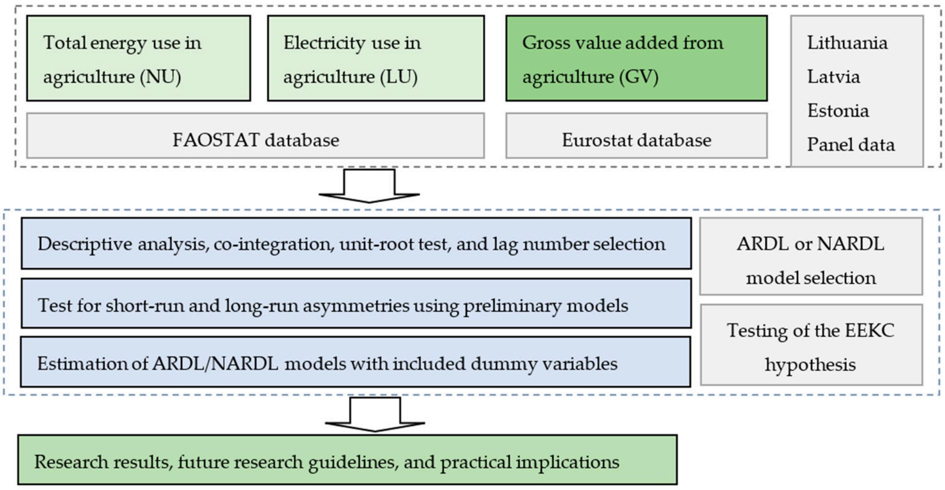

Figure 1. The study's research framework.

The study investigates the energy–environmental Kuznets curve hypothesis that as gross added value grows over time, the growth rate of energy use slows, and, finally, the quantity of energy used decreases. It is accomplished via the use of ARDL modelling, which is similar to the error correction model (ECM) approach and is founded on an ordinary least square (OLS) model, but that is also suitable for time series that are non-stationary and have varied order of integration [61]. In this instance, energy use, the dependent variable, has a long-term effect and short-term effect parameters for their influences on the first-level difference in the ARDL model. Therefore, the ARDL model is a type of unconstrained ECM because all of the long-term relationship variables are defined but not bound:

$$\Delta Y_t = \mu + \rho Y_{t-1} + \theta X_{t-1} + \sum_{i=1}^{p} a_i \Delta Y_{t-1} + \sum_{i=0}^{q-1} \omega_i \Delta X_{t-1} + D + S + \varepsilon_t,$$

where Y is the dependent variable; X is the independent variable; μ, ρ, θ, a, ω are model parameters; D and S are dummy variables; ε_t is the residual error; Δ is the difference in the first order; i is the time lag; p is the number of time lags for differences in Y; q is the number of time lags for differences in X; and t is the time.

As indicated in the previous section, the main research issue gives asymmetries many emphases. In order to simulate nonlinearities, co-integration, and causality simultaneously, the non-linear NARDL model is utilised. The distributed lag non-linear autoregressive distributed lag (NARDL) is an error correction model with a single equation that incorporates short- and long-run nonlinearities by using partial sum decompositions of positive and negative changes in the explanatory variables [62]. Using partial sum decompositions of the independent variable, this method assesses the asymmetry inside the long-run equilibrium relationship in addition to the short-run dynamic coefficients. Consequently, the gross value added (GV) is divided into its positive and negative components, GV^+ and GV^-. The long-run indicators are the sums of these components: $GV_t^- = \sum_{i=1}^{t} \Delta GV_i^-$ and $GV_t^+ = \sum_{i=1}^{t} \Delta GV_i^+$. Then, NARDL modelling is then performed where GV is X, or LU is Y:

$$\Delta Y_t = \mu + \rho Y_{t-1} + \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + \sum_{i=1}^{p} a_i \Delta Y_{t-1} + \sum_{i=0}^{q-1} \left(\omega_i^+ \Delta X_{t-1}^+ + \omega_i^- \Delta X_{t-1}^- \right) + D + S + \varepsilon_t,$$

where Y is the dependent variable; X^+ is the sum of positive differences in the independent variable; X^- is the sum of negative differences in the independent variable; D and S are dummy variables; D and S are dummy variables; μ, ρ, θ^+, θ^-, a, ω^+, ω^- are model parameters; ε_t is the residual error; Δ is the difference in the first order; i is the time lag; p is the number of time lags for differences in Y; q is the number of time lags for differences in X; and t is the time.

Before performing ARDL/NARDL modelling, it is also determined whether the data's time series are suitable for this analysis; an ADF test [63] is performed to assess stationarity when using the model that includes and excludes a time trend, and an Engle-Granger co-integration test [64] is performed to determine whether these time series are co-integrated with each other.

Preliminary time series models are estimated to identify the best number of time lags (q and p), using the number of time lags that provide preliminary ARDL models with the lowest values of the information criteria values. As in research by other authors using AR models [22,65], we choose to use three information criteria: the Hannan-Quinn information criterion, the Akaike information criterion, and the Schwartz information criterion. Then we estimate what number of differences in Y (named by p) and what number of differences in X (named by q) provide the lowest values of these information criteria.

The models also incorporate dummy variables. The research employs two time dummy variables to depict major events in the economic progress of the Baltic nations. This is during 2009 (dummy variable named as D_2009), when the economic crisis hit, causing a drop in gross added value, and since 2004, when all three nations joined the EU (dummy variable named as S_2004).

Two additional statistical hypotheses are tested when the models are estimated: h_1: $\rho = \theta = 0$ and h_2: $\omega_0 = \omega_1 = \omega_2 = 0$. The second hypothesis, $h_{2,}$ tests if the joint short-run effect of gross value added from all time lags is equal to zero. Some variables from the ARDL equation must be removed using the Wald test [66] based on the covariance matrix to test hypotheses.

The statistical reliability of the models, the p-values of the parameter estimates, the coefficient of determination R^2, the test of the normal distribution of the residual errors, and the test of their stationarity and autoregressive heteroskedasticity (ARCH) are all evaluated when analysing the estimates of the models.

The following models are calculated using a Gretl 2019a software technique. Using the sequential elimination of variables from models, insignificant factors with p-values of less than 0.05 are eliminated, leaving only the most significant variables that best describe the dynamics of energy usage. The QLR test is used to examine if structural breaks persist when time dummy variables are removed from the models and shown to be statistically insignificant. The QLR test is a variant of the Chow test [67] that uses the highest F statistic generated when the Chow test is performed on all probable break dates within a specified range. The analysis determines the observation at which the most significant value of the F statistic occurs using the default cut of 15%. The likelihood of this structural rupture is evaluated using the chi-square asymptotic p-value. The crucial value for the QLR at 5% is then noticed.

3. Results

The time series descriptive statistics for all three countries are presented below (see Figure 2 and Table 1). The average total energy use (NU) in agriculture is highest in Latvia (5869.0) and lowest in Estonia (4258.0). On the other hand, the average electricity use (LU) in the considered period is the lowest in Latvia (592.29) and the highest in Estonia (774.75). Gross value added in agriculture (GV) is highest in Lithuania (mean is 1761.8) and least in Estonia (mean is 632.65). The variation in total energy use is the largest in Lithuania (25.63% of the mean) and the smallest in Latvia (8.85% of the mean). The variation in electricity use is also the largest in Lithuania (39.52% of the mean) and the smallest in Latvia (12.54% of the mean). The variation in gross value added created in agriculture is the largest in Estonia (29.06% of the mean) and the smallest in Lithuania (18.66% of the mean). The averages of changes in energy use are negative values except for Estonia when analysing the total energy use (here, the mean is 61.819). This shows that energy use decreased in most cases during the considered period.

Table 1. Descriptive statistics of total energy use by agriculture (NU), electricity use by agriculture (LU), and gross value added generated by agriculture (GV).

Indicator	Lithuania			Latvia			Estonia		
	NU	LU	GV	NU	LU	GV	NU	LU	GV
Using initial value LU, NU, and GV:									
Mean	4307.7	806.43	1761.8	5869.0	592.29	995.89	4258.0	774.75	632.65
Median	3998.9	702.00	1732.7	5904.8	583.20	964.90	4271.1	748.80	628.85
Minimum	3513.9	597.60	1097.4	5071.6	486.00	541.10	2086.4	565.20	341.30
Maximum	8098.9	1803.6	2300.0	6770.1	741.60	1658.4	5636.7	1227.6	922.20
Standard deviation	1104.0	318.72	328.80	519.38	74.287	274.39	911.93	135.45	183.85
Standard deviation, %	25.63	39.52	18.66	8.85	12.54	27.55	21.42	17.48	29.06
Skewness	2.4063	2.2518	−0.1019	0.0167	0.3252	0.4071	−0.6930	1.5051	−0.0544
Kurtosis	4.8291	3.5790	−0.9646	−0.9212	−0.9454	−0.0311	0.2617	3.4275	−1.2993
Using differences of variables ΔNU, ΔLU and ΔGV:									
Mean	−171.53	−45.420	20.625	−3.3928	−8.3100	31.579	61.819	−31.350	20.458
Median	−22.250	−12.600	4.8500	−16.513	−1.8000	7.5500	84.350	−12.600	41.700
Minimum	−2014.1	−676.80	−591.10	−933.15	−158.40	−161.80	−1297.0	−338.40	−294.70
Maximum	413.50	54.000	385.30	820.84	57.600	256.90	1702.3	126.00	271.10
Standard deviation	538.75	152.79	251.12	392.44	50.284	113.69	593.90	107.49	126.98
Skewness	−2.0762	−3.2051	−0.2809	−0.1506	−1.2029	0.2821	0.2617	−1.4470	−0.4026
Kurtosis	4.3213	10.495	−0.2259	0.3954	1.5072	−0.9983	1.6694	2.4072	0.2846
Mean	−171.53	−45.420	20.625	−3.3928	−8.3100	31.579	61.819	−31.350	20.458

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

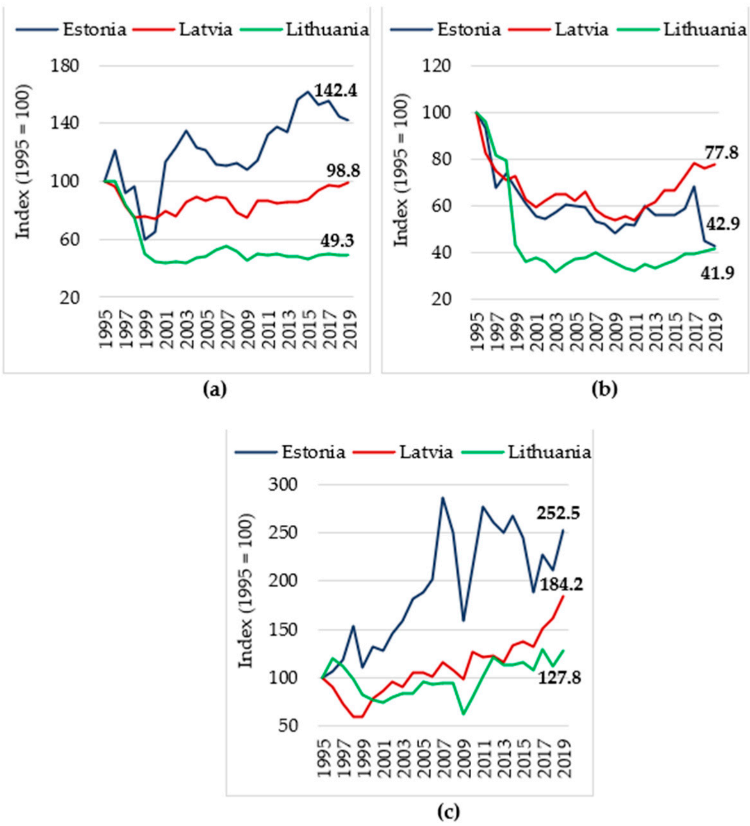

Figure 2. Baltic States time series: (**a**) total energy use in agriculture (NU); (**b**) electricity use in agriculture (LU); (**c**) Gross value added generated by agriculture (GV). Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Below are the results of the ADF test (see Table 2). In most cases, time series are stationary and do not have a unit root, but only when analysed with first-level differences. Using first-level differences, the time series are stationary in all cases except for electricity use (LU) in Estonia. The time series of total energy use (NU) in Estonia and the time series of electricity use (LU) in Lithuania are stationary only when applying the test with a constant.

Table 2. Augmented Dickey–Fuller test results.

Indicator	Lithuania			Latvia			Estonia		
	NU	**LU**	**GV**	**NU**	**LU**	**GV**	**NU**	**LU**	**GV**
Using initial values LU, NU and GV, *p*-values:									
test without trend	0.0345	0.0017	0.4117	0.359	0.3797	0.9911	0.5513	0.1391	0.2725
test with trend	0.2165	0.9182	0.9323	0.3374	0.7259	0.1241	0.0593	0.2096	0.1693
Using differences of variables ΔNU, ΔLU and ΔGV, *p*-values:									
test without trend	0.0023	0.0101	0.0003	0.0023	0.0012	0.0016	0.0417	0.1902	<0.0001
test with trend	0.0016	0.2236	0.0043	0.0144	0.0156	0.0194	0.0942	0.3326	<0.0001

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

The results of the co-integration test show that the time series are mostly co-integrated with each other when analysing Latvian data (see Table 3). Lithuanian data are less co-integrated with each other; in all cases, *p*-values are higher than 0.05. When analysing Latvian data, the time series using first-level differences are co-integrated in all cases, but when applying absolute values, only the time series of gross value added (GV) and total energy use (LU) are co-integrated. In the case of Estonia, only the time series of first-level differences and the time series of electricity use (LU), but not the total energy use (NU), are co-integrated. The fact that the series are co-integrated with each other in some instances justifies the need to use ARDL models in further analysis.

Table 3. Engle–Granger co-integration test results.

Indicator	Lithuania		Latvia		Estonia	
	NU	**LU**	**NU**	**LU**	**NU**	**LU**
Using initial values LU, NU and GV, *p*-values:						
test without trend	0.1592	0.0989	0.0464	0.7406	0.2304	0.3236
test with trend	0.5530	0.4428	0.1895	0.8000	0.2447	0.7029
Using differences of variables ΔNU, ΔLU and ΔGV, *p*-values:						
test without trend	0.3984	0.1892	0.0140	0.0346	0.0805	0.0023
test with trend	0.6988	0.1535	0.0436	0.0526	0.2108	0.0172

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Next, preliminary NARDL models are built to determine the optimal number of time lags (see Appendix A). Considering the minimum values of the information criteria, the appropriate number of time lags was selected for further analysis. When analysing Lithuanian data, it is chosen to apply two time lags of energy use ($p = 2$) and one time lag of gross value added ($q = 1$) in terms of both NU and LU. When analysing Latvian data and applying total energy use, it is chosen to apply two time lags for NU ($p = 2$) and one time lag for GV ($q = 1$). When analysing electricity use, it is chosen to apply one time lag for LU ($p = 1$) and three time lags for GV ($q = 3$). When analysing Estonian data and applying total energy use, it is chosen to apply two time lags for NU ($p = 2$) and three time lags for GV ($q = 3$). When analysing electricity use, it is chosen to apply two time lags for LU ($p = 2$) and one time lag for GV ($q = 1$). When analysing the panel data, two time lags of energy use ($p = 2$) and one time lag of gross added value ($q = 1$) are chosen for both NU and

LU. Next, a preliminary NARDL model is constructed, and hypotheses are tested that the long-run and short-run effects are symmetrical (see Table 4). In the cases of both Lithuania and Estonia, the time effects are symmetrical when examining total energy use (NU). In the cases of Estonia and panel data, short-term asymmetries have been identified. This suggests that gross value added (GV) explains energy use in the short run but that this effect is asymmetric in nature. When examining electricity use (LU), the hypothesis that this relationship is symmetrical is accepted in all cases. In summary, it can be said that in all cases, the ARDL model will be applied for further analysis, except for Estonia and panel data, where the NARDL model will be applied but only when modelling total energy use (NU).

Table 4. Results of tests for long- and short-run symmetry.

Time Period	Long Run, *p*-Value	Short Run, *p*-Value	Conclusion
Using NU and GV:			
Lithuania	0.8071	0.5781	No asymmetry
Latvia	0.7285	0.5901	No asymmetry
Estonia	0.2277	0.0511	Short-run asymmetry
All Baltic States	0.9135	0.0605	Short-run asymmetry
Using LU and GV:			
Lithuania	0.2450	0.7645	No asymmetry
Latvia	0.2226	0.5955	No asymmetry
Estonia	0.6729	0.4765	No asymmetry
All Baltic States	0.5922	0.5577	No asymmetry

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

First of all, the parameter estimates of the ARDL models of the Lithuanian NU and LU models are analysed (see Table 5). Both NU (−1) and LU (−1) energy use are statistically significant (p-value < 0.05) and negative. It shows that as the level of energy use increases, the growth rate of energy use slows down. Analysing the NU model, it was also observed that the constant is positive and statistically significant. All other parameters, including time dummy variables, are statistically insignificant. The NU model explains the dynamics better than the LU model, with a higher R^2 of 0.7621. The residual errors of both models are not normally distributed (p-value < 0.05), but they are stationary when applying the model without or with a trend. Residual errors are also characterised by statistically significant ARCH effects (p-value < 0.05). Models after the sequential elimination of insignificant variables are provided in the appendices (see Appendix B). In reduced models, the constants are statistically significant and positive in both models. In the NU model, changes in energy use with a two-year time lag ΔNU (−2) are also statistically significant and positive. When applying the NU model, its residual errors are normally distributed. The time dummy variables are removed from the model, the QLR test is performed, and the structural breaks for both models are found to be in the year 2000.

Next, the parameter estimates of the ARDL models of the Latvian NU and LU models are analysed (see Table 6). Only NU (−1) is statistically significant (p-value < 0.05) and negative. It shows that as the level of energy use increases, the growth rate of energy use slows down. Analysing the NU model, it was also observed that the constant is positive and statistically significant. GV (−1) is statistically significant in both models and positive, showing that as gross value increases, so does energy use. ΔGV (−1) is statistically significant in the LU model but has a negative parameter value. All other parameters, including time dummy variables, are statistically insignificant. The LU model explains the dynamics better than the NU model, with a higher R^2 of 0.6333. Both models' residual errors are normally distributed (p-value > 0.05), and they are stationary when applying the model without a trend. In addition, residual errors are not characterised by statistically significant ARCH effects (p-value > 0.05). Models after the sequential elimination of insignificant variables are provided in the appendices (see Appendix C). The NU model shows similar parameter estimates, except that GV (0) is positive here and statistically significant. In the LU model, the time dummy variable S_2004 is also statistically significant and has a negative sign, showing that electricity use in agriculture decreased after the country joined the EU. As the time dummy variables are removed from the model, the QLR test is performed, and the structural break for the NU model is found to be in the year 2005.

Table 5. Autoregressive distributed lag (ARDL) estimations for Lithuania.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	1836.8600	0.0078	Constant	29.7719	0.8978
NU (−1)	−0.4046	0.0020	LU (−1)	−0.4182	0.0147
GV (−1)	−0.1888	0.5496	GV (−1)	0.1323	0.3130
ΔNU (−1)	−0.0554	0.7337	ΔLU (−1)	−0.1424	0.5091
ΔNU (−2)	0.3260	0.0611	ΔLU (−2)	−0.0064	0.9768
ΔGV (0)	0.1474	0.7384	ΔGV (0)	0.0985	0.5898
S_2004	150.5100	0.5680	S_2004	24.2027	0.8294
D_2009	−461.0290	0.3123	D_2009	25.6639	0.8896
Auxiliary hypotheses: h_1: reject, *p*-value 0.0028 h_2: accept, *p*-value 0.7384 Supplementary estimations, *p*-values: A normality test: 0.0294 ADF test of residual (without trend): <0.0001 ADF test of residual (with trend): 0.1416 ARCH effect: 0.0069 R-squared: 0.7621			Auxiliary hypotheses: h_1: reject, *p*-value 0.0453 h_2: accept, *p*-value 0.5898 Supplementary estimations, *p*-values: A normality test: <0.0001 ADF test of residual (without trend): 0.0666 ADF test of residual (with trend): 0.0003 ARCH effect: 0.0006 R-squared: 0.5563		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Table 6. Autoregressive distributed lag (ARDL) estimations for Latvia.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	3822.0900	0.0068	Constant	51.3900	0.4677
NU (−1)	−0.8715	0.0034	LU (−1)	−0.2736	0.0574
GV (−1)	1.1756	0.0358	GV (−1)	0.1562	0.0257
ΔNU (−1)	0.0278	0.8851	ΔLU (−1)	0.0853	0.6659
ΔNU (−2)	0.0602	0.7623	ΔGV (0)	−0.0500	0.4712
ΔGV (0)	1.0893	0.1233	ΔGV (−1)	−0.2067	0.0211
S_2004	149.9530	0.5260	ΔGV (−2)	0.0777	0.3146
D_2009	−554.4930	0.1354	S_2004	−46.5306	0.1262
			D_2009	−61.0039	0.0935
Auxiliary hypotheses: h_1: reject, *p*-value 0.0106 h_2: accept, *p*-value 0.1233 Supplementary estimations, *p*-values: A normality test: 0.8378 ADF test of residual (without trend): 0.0001 ADF test of residual (with trend): 0.6360 ARCH effect: 0.5394 R-squared: 0.5608			Auxiliary hypotheses: h_1: accept, *p*-value 0.0597 h_2: reject, *p*-value 0.0322 Supplementary estimations, *p*-values: A normality test: 0.1525 ADF test of residual (without trend): 0.0002 ADF test of residual (with trend): 0.2104 ARCH effect: 0.6933 R-squared: 0.6333		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Next, the parameter estimates for the Estonian NU NARDL and LU ARDL models are analysed (see Table 7). Both NU (−1) and LU (−1) energy use are almost statistically significant (*p*-value is near 0.05) and negative. GV (−1) is only statistically significant in the NU model and has a positive sign. All other parameters, including time dummy variables, are statistically insignificant. The NU model explains the dynamics better than the LU model, with a higher R^2 of 0.7203. The residual errors of both models are normally distributed (p-value < 0.05), and they are stationary in the NU model. Residual errors are also characterised by statistically significant ARCH effects in the LU model (p-value < 0.05). Models after the sequential elimination of insignificant variables are provided in the appendices (see Appendix D). In the NU model, ΔGV^{-} (-2) is almost statistically significant (p-value = 0.0679), showing short-run asymmetry and a negative sign. In the LU model, LU (-1) is statistically significant and has a negative sign, showing that electricity use moves at a decreasing rate in the long run. However, neither model has normally distributed residual errors or ARCH effects. The time dummy variables are removed from the model, the QLR test is performed, and the structural breaks for both models are found to be in 2002 when applying the NU model, but there is no statistically significant structural break (unexpected change in parameter values) when analysing the LU model.

Table 7. Non-linear autoregressive distributed lag (NARDL) estimations for Estonia.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	967.8790	0.3635	Constant	454.4330	0.1450
NU (−1)	−0.5659	0.0556	LU (−1)	−0.5474	0.0813
GV (−1)	3.5800	0.0279	GV (−1)	−0.1455	0.5428
ΔNU (−1)	0.2452	0.2689	ΔLU (−1)	−0.1907	0.4072
ΔNU (−2)	0.2502	0.2985	ΔLU (−2)	−0.2834	0.3253
ΔGV+ (0)	−1.7686	0.3538	ΔGV (0)	−0.0880	0.7304
ΔGV+ (−1)	−2.9727	0.1935	S_2004	52.1898	0.5847
ΔGV+ (−2)	−3.5118	0.1361	D_2009	−118.2060	0.3424
ΔGV− (0)	6.1739	0.0618			
ΔGV− (−1)	−0.4214	0.8167			
ΔGV− (−2)	−2.4054	0.2168			
S_2004	1247.9400	0.2461			
D_2009	−302.6480	0.6116			
Auxiliary hypotheses: h_1: reject, *p*-value 0.0295 h_2: accept, *p*-value 0.0861 Supplementary estimations, *p*-values: A normality test: 0.3319 ADF test of residual (without trend): 0.0011 ADF test of residual (with trend): <0.0001 ARCH effect: 0.3966 R-squared: 0.7203			Auxiliary hypotheses: h_1: accept, *p*-value 0.2049 h_2: accept, *p*-value 0.7304 Supplementary estimations, *p*-values: A normality test: 0.0732 ADF test of residual (without trend): 0.0694 ADF test of residual (with trend): 0.2552 ARCH effect: 0.0109 R-squared: 0.3297		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Finally, the parameter estimates for the panel NU NARDL and LU ARDL models are analysed (see Table 8). Both NU (-1) and LU (-1) energy use are statistically significant (p-value < 0.05) and negative. It shows that as the level of energy use increases, the growth rate of energy use slows down. Constants are statistically significant and have positive signs in both models. All other parameters, including time dummy variables, are statistically insignificant. The LU model explains the dynamics better than the NU model, with a higher R^2 of 0.3799. The residual errors of both models are not normally distributed (p-value < 0.05), and they are not stationary when applying the model without or with a trend. There are no tools to reduce and subsequently remove insignificant variables from panel data models.

In conclusion, ARDL and NARDL models can be used to examine how energy use and gross value added (GV) in agriculture in different states are related. The optimal number of time lags for each state's model was chosen by estimating preliminary ARDL models and then determining at what time lags (p and q) the information criteria values were the smallest.

Table 8. Non-linear autoregressive distributed lag (NARDL) estimations for panel data of all three Baltic countries.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	833.8770	0.0046	Constant	191.2130	0.0024
NU (−1)	−0.1451	0.0122	LU (−1)	−0.3244	<0.0001
GV (−1)	−0.2740	0.1597	GV (−1)	−0.0001	0.9967
ΔNU (−1)	0.1429	0.2109	ΔLU (−1)	−0.0908	0.3841
ΔNU (−2)	0.1000	0.3739	ΔLU (−2)	0.0204	0.8590
ΔGV+ (0)	0.1307	0.6001	ΔGV (0)	0.0262	0.7307
ΔGV− (0)	0.0113	0.9735	S_2004	28.0108	0.4087
S_2004	105.8500	0.5649	D_2009	−45.1588	0.4546
D_2009	−318.8850	0.2711			
Auxiliary hypotheses: h_1: reject, *p*-value 0.0065 h_2: accept, *p*-value 0.7343 Supplementary estimations, *p*-values: A normality test: <0.0001 ADF test of residual (without trend): 0.3296 ADF test of residual (with trend): 0.8198 R-squared: 0.2496			Auxiliary hypotheses: h_1: reject, *p*-value < 0.0001 h_2: accept, *p*-value 0.7307 Supplementary estimations, *p*-values: A normality test: <0.0001 ADF test of residual (without trend): 0.3739 ADF test of residual (with trend): 0.1441 R-squared: 0.3799		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

4. Discussion

4.1. Comparison with Previous Studies

The results of this study allow us to expand the already available field of knowledge on the topic of the relationship between economic growth and energy use. In the works of other authors on this topic, economic growth, its connections with environmental safety aspects, GHG emissions, and energy consumption levels are mostly explored. The studies focus mainly on the developed countries of the world [26,70], but recent studies also analyse more broadly the less developed countries [23,30,71]. Some studies analyse data from several countries together, such as the EU countries [72]; others focus on the EU agricultural sector [73]; panel studies are also conducted [47,74–76]. On the other hand, there are some studies that specifically analyse the Baltic countries in these aspects [76–81], studies that focus more on testing the energy–Kuznets curve hypothesis in the Baltic States [82], and studies that focus exclusively on Lithuania [83]. The EEKC curve hypothesis was used in this study, which has not yet been broadly used in studies by other authors. It, in turn, characterises better the relationship between environmental quality, energy consumption, and economic growth. For a long time, the Baltic countries were planned economic states that belonged to the USSR. For them, in 1990–1991, after the restoration of independence and in 2004, after becoming members of the EU, the economy began to grow rapidly, and the service sector developed, as is typical of post-industrial countries. The study failed to identify a statistically significant inverted "U" curve effect in the Baltic countries. This essentially supports the observation of other authors that this effect is characteristic of states with historically developed economies [33] (it is not characteristic of the Baltic countries).

Although other authors [82,83] have used similar methodologies in their work, this study used the latest data on the Baltic countries, specifically the agricultural sector, which has not yet been analysed. The contradictory nature of research results is determined by the level of development of countries, the possibilities of replacing fossil fuels with renewable energy sources, as well as the research methods used. In the Baltic countries, the importance of agriculture to the country's economy (as measured by the gross added value created) is higher than on average in the EU countries. In the Baltic countries, the agricultural sector still employs a relatively large share of the employed, and the income level and development of the population in rural areas depend on this sector. Another important aspect is that the added value created in the agriculture of the Baltic countries has the potential to increase by increasing the efficiency of the resources used. The study also used several energy consumption indicators (total energy and electricity consumption) and analysed structural break points (the financial crisis period of 2009 and countries' membership in the EU). Electricity consumption was analysed separately from total energy consumption, assuming that electricity consumption is less polluting. The research focuses on agriculture and allows for a better study of the interactions between the gross added value created in agriculture, as expressed by economic growth, and the energy consumption in agriculture. The main observations of the study can be divided into several groups:

First, the study identified cases where short-term changes in economic growth measured by gross value added increased total energy consumption and electricity consumption. The short-term effects of economic growth are more noticeable when analysing total energy consumption than electricity consumption. These effects were mainly observed when analysing data from Latvia and Estonia but not from Lithuania. Other authors who were testing both the Kuznets environmental curve hypothesis through the lenses of energy use or GHG emissions also found similar effects: that GDP growth mostly affects energy use in more developed countries [23,84] or that the gross value added from agriculture is insignificant in some countries [85]. Authors who have mainly used energy consumption [86,87] have emphasised such problematic aspects of agriculture that alternative resources gradually replace the volume of energy consumption. In addition, this study demonstrates that relations of an asymmetric nature were identified in the analysis of Estonian data. Other authors who applied the NARDL model observed such effects but found asymmetric relationships in long-term effects [88]. Some studies also focus on electricity consumption [47,89,90], emphasising that a large part of the electricity is produced from renewable resources.

Another important observation in this study is that energy consumption increases when moving at a decreasing rate. A negative long-term effect parameter (NU) of energy consumption was found to be statistically significant in all cases, with similar results obtained when analysing countries separately and using panel data. On the other hand, it was not established that the gross added value would have a statistically significant negative long-term effect parameter (GV) on energy consumption, so the environmental hypothesis of Kuznets' inverted "U" curve cannot be fully accepted since it cannot be said that energy consumption would start to decrease after reaching a certain level. Other authors have also not always accepted or rejected the environmental Kuznets curve hypothesis for all states [88,91], as the hypothesis is mainly accepted in industrialised or developed countries [24,26]. When analysing data from the Baltic countries, other authors used different indicators, such as CO_2, but rejected these links as well [78]. The energy–Kuznets curve hypothesis is accepted in the most developed economies but not in low- to middle-income countries [23,71]. According to Filippidis et al. [47], who analysed panel data from more than 200 countries in 2021, the inverted U-energy Kuznets hypothesis is accepted, and the relationship between renewables and economic growth is simply a U-shaped curve. In addition, an "N"-shaped energy–Kuznets curve is observed [48]. However, this hypothesis was rejected by other authors who tested the energy–Kuznets curves of the Baltic countries [82]. The results of the study show that it can be assumed that the economies of the Baltic countries jumped to a higher level of economic development, skipping some stages of economic development that the economies of Western Europe went through, due to the changes that occurred in the economies of Central and Eastern Europe during the period of economic transformation when moving from a planned to a market economy.

Furthermore, suspected structural breaks (unexpected changes in parameter values) are characterised by dummy time variables, showing the major impacts on the agricultural sector of the Baltic countries: as assessed in 2008, the crisis, which had a significant impact on the economies of all three Baltic countries, and the period since joining the EU in 2004, when the volume of subsidies in the agriculture of the Baltic countries increased, the structure of agricultural exports changed, among others. When assessing structural breaks and the influence of economic crises on the shape of the curve, statistically significant breaks were identified only when analysing Latvian data. The results of the study suggest that Latvia's accession to the EU had a negative impact on electricity consumption in agriculture. No such relationships were observed when analysing the data from other countries. On the other hand, it was observed that an unexpected change in parameter values in the analysis of Lithuanian data could be around 2000, based on QLR test results. Other authors also observed similar statistically significant structural breaks or economic changes in countries where they tested the EKC hypothesis [92].

4.2. Proposals for Future Research

The study's main limitation is that the data were used only from 1995 since only that much data is available for the Baltic countries. Other studies have used longer time series significantly, reaching as far back as the 1970s, which provides more flexibility in choosing the ARDL econometric models to be applied [88,93]. The study also found little success in identifying asymmetric relationships. The conventional ARDL model was chosen to be applied more often than the NARDL model, which was often used in the works of other authors [88,94,95]. Other authors were able to identify not only short-term but also long-term asymmetric relationships [88].

As more data become available, the study can be expanded to include new crises related to the global health crisis and the tense political situation after 2022. During this period, the prices of agricultural products rose rapidly, and the standard of living fell, which may have led to changes in the relationship between gross value added and energy consumption in agriculture. Therefore, more dummy variables could be included in the research models. Other authors have already analysed the post-2020 periods and identified such problematic aspects as asymmetric impacts, as the long-run impact of the positive shock on oil prices is not similar to the negative shock [94]. In the study, structural breaks could be more detailed by choosing separate breaking points for individual states. As shown by the results of the QLR test for Lithuanian data, typical changes occurred around 2000.

The study could be further expanded by using more indicators covering economic growth. Other authors have used different indicators: the implementation of technological innovations in agriculture [95,96], the importance of foreign investment and trade openness [97–99], economic development [1,30], government interventions, the extent of renewable energy use [84,100–102], and other factors influencing energy consumption [103,104].

More sophisticated methods may also be used in the study. For example, methods that other authors employed in their studies include the ARDL cumulative sum (CUSUM) test [105], the dynamic ARDL [106], the bootstrap ARDL [107], the Granger test [24,85], the panel regression model [23], multilevel mixed-effects models [82], and non-parametric analysis [24].

4.3. Practical Implications

The study analysed the three Baltic States due to their comparable agricultural structures, similar production conditions, and the fact that these countries apply the Common Agricultural Policy. The General Agricultural Policy 2023–2027, not only in the Baltic countries but also in all EU countries, will be more focused on sustainable solutions to environmental problems, which can reduce the amount of greenhouse gas emissions and contribute to the implementation obligations of the green course and net zero goals.

The study results showed that an inverted "U" could not be established, but in all three states, energy consumption moves at a decreasing rate as gross value added increases. On the one hand, either these countries have not yet reached a level of economic development that is characterised by declining energy consumption, or the countries did not previously have a developed industrial sector and a rich agricultural sector and immediately transitioned to a service economy, which is why there is no clear and sloping inverted "U" curve. On the other hand, it shows that economic growth alone is not enough to solve environmental problems. The findings suggest that the government should prioritise carbon reduction measures and implement such policies more effectively at the national level.

Other authors, following their research findings, suggest different measures to manage energy use and greenhouse gas emissions in agriculture. The economic openness and financial development of the country are emphasised [97,98,108]. Others emphasise the importance of renewable energy sources [109,110]. It is especially important as in the Baltic countries, renewable energy sources are still not widely used. The study results could serve the Baltic countries in setting indicative national goals for reducing energy consumption in agriculture and finding opportunities to switch to renewable energy and increase energy efficiency to reduce greenhouse gas emissions by 2050, neutralising the impact on the climate [3].

5. Conclusions

This study examines the relationship between energy consumption in agriculture and the gross value added in agriculture. The research aims to supplement the already-existing field of knowledge and better explain the formation of these connections. The study uses countries less analysed in the works of other authors, and the study analyses the annual data of all three Baltic countries together and separately from 1995 to 2019. Since all three countries have similar agricultural systems and environmental aspects, the research results are comparable and provide new insights. The research used not only the total energy consumption in agriculture but also the electricity consumption in agriculture, as well as focusing on the entry of countries into the EU and the impact of the economic crisis. More complex time series models, such as ARDL and NARDL, were used to model these relationships and test whether they take an inverse or asymmetric shape over time. The study analyses whether, as gross value added increases, energy consumption increases up to a certain level and then starts to decrease.

The study led to three major conclusions. First of all, energy consumption increases but moves at a decreasing rate. A negative long-term effect parameter (NU) was found to be statistically significant in all cases, and similar results were obtained when analysing countries separately and panel data. On the other hand, it was not established that added value would have a statistically significant negative long-term effect parameter (GV) on energy consumption, so the environmental hypothesis of Kuznets' inverted "U" curve cannot be entirely accepted. The conclusion of the study is basically similar to the results obtained by other researchers. The originality of the research lies in the fact that the relationship between energy use and economic growth in agriculture is investigated, and ARDL and NARDL models are applied to compare energy use to electricity use. To our knowledge, such a study has not been carried out before in the agriculture of the Baltic countries. On the other hand, short-term changes in economic growth increase total energy consumption and electricity consumption in most cases. Short-term effects are more noticeable when analysing total energy consumption than electricity consumption. These effects were mainly observed when analysing data from Latvia and Estonia but not from Lithuania. In the analysis of Estonian data, relations of an asymmetric nature were identified. Moreover, when assessing structural breaks and the influence of economic crises on the shape of the curve, a statistically significant time dummy variable was identified only when analysing Latvian data. The results of the study suggest that Latvia's accession to the EU had a negative impact on electricity consumption in agriculture. No such relationships were observed when analysing the data from other countries. On the other hand, it was observed that the structural break in the analysis of Lithuanian data could be around 2000. For Kuznets' hypothesis to be true, the energy produced from fossil fuels must be replaced more rapidly by energy produced from renewable energy sources in agriculture. It could also be influenced by the advanced production technologies, innovations and modernisation used in the production of agricultural products.

The data used in the study goes back only to 1995, as only that much data were available for all three Baltic countries. Other studies, which mainly analysed the economies of developed countries, tested the Kuznets curve hypothesis with much longer data series, which led to more flexibility in applying econometric models. On the other hand, the study can be expanded with the availability of more data. New crises related to the global health crisis and the tense political situation after 2020 may be included in the study. During this period, the prices of agricultural products rose rapidly, and the standard of living fell, which may have led to changes in the relationship between economic growth and energy consumption in agriculture. Therefore, more dummy variables could be included in the research models. The study could include more countries and compare results between eastern and western European countries. The study can also use more indicators showing environmental aspects and pollution.

The results of the study have important practical suggestions for further policy-making for policy makers who want to make decisions about energy efficiency in order to improve the quality of the environment while ensuring economic growth.

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Appendix A

Table A1. Information criteria for best time lag selection.

Information Criteria	Schwarz Criterion			Akaike Criterion			Hannan-Quinn Criterion		
Time Lag	$q = 1$	$q = 2$	$q = 3$	$q = 1$	$q = 2$	$q = 3$	$q = 1$	$q = 2$	$q = 3$
Using NU and GV:									
$p = 1$	347.3501	353.1688	341.3105	339.4016	342.9494	329.3090	341.4006	345.5195	332.1362
$p = 2$	328.5817	334.6953	340.3131	319.8534	323.7848	327.2206	321.9095	326.3550	330.3048
Latvia									
$p = 1$	338.9816	342.9144	332.6672	331.0332	332.6950	320.6657	333.0322	335.2652	323.4929
$p = 2$	328.7566	332.6071	335.7460	320.0283	321.6967	322.6535	322.0844	324.2669	325.7377
Estonia									
$p = 1$	363.8117	368.5495	353.2095	355.8632	358.3300	341.2080	357.8622	360.9002	344.0352
$p = 2$	347.1741	352.0053	348.5405	338.4458	341.0949	335.4480	340.5019	343.6650	338.5322
Panel									
$p = 1$	1059.215	1066.471	1020.847	1043.576	1046.364	996.7609	1049.781	1054.341	1006.278
$p = 2$	1008.419	1016.439	1024.166	990.9015	994.5423	997.8898	997.8234	1003.195	1008.273
Using LU and GV:									
Lithuania									
$p = 1$	296.0494	301.9561	293.5428	288.1009	291.7367	281.5414	290.0999	294.3068	284.3686
$p = 2$	286.9268	291.7369	296.6200	278.1985	280.8264	283.5275	280.2546	283.3966	286.6117
Latvia									
$p = 1$	242.1129	241.2186	235.3446	234.1645	230.9992	223.3432	236.1635	233.5693	226.1703
$p = 2$	235.8228	235.3802	238.4298	227.0944	224.4697	225.3373	229.1506	227.0399	228.4215
Estonia									
$p = 1$	284.8172	289.8978	280.4342	276.8688	279.6784	268.4327	278.8678	282.2486	271.2599
$p = 2$	274.6944	277.2970	280.5093	265.9661	266.3866	267.4168	268.0222	268.9567	270.5010
Panel									
$p = 1$	829.5992	837.5174	802.6740	813.9605	817.4105	778.5878	820.1649	825.3876	788.1054
$p = 2$	796.4406	803.4549	806.0290	778.9233	781.5583	779.7532	785.8452	790.2107	790.1360

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Appendix B

Table A2. ARDL estimations for Lithuania after eliminating insignificant variables.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	1848.5800	<0.0001	Constant	289.7310	0.0014
NU (−1)	−0.4621	<0.0001	LU (−1)	−0.4248	0.0003
ΔNU (−2)	0.3126	0.0128			
Auxiliary hypotheses: h_1: reject, *p*-value < 0.0001 Supplementary estimations, *p*-values: A normality test: 0.3113 ADF test of residual (without trend): 0.7711 ADF test of residual (with trend): 0.9966 ARCH effect: 0.0201 R-squared: 0.6961 QLR test *p*-value: <0.0001, year: 2000			Auxiliary hypotheses: h_1: reject, *p*-value 0.0003 Supplementary estimations, *p*-values: A normality test: <0.0001 ADF test of residual (without trend): <0.0001 ADF test of residual (with trend): <0.0001 ARCH effect: 0.0017 R-squared: 0.4852 QLR test *p*-value: <0.0001, year: 2000		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Appendix C

Table A3. ARDL estimations for Latvia after eliminating insignificant variables.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	2867.7000	0.0072	Constant	32.1794	0.6094
NU (−1)	−0.6936	0.0045	LU (−1)	−0.2873	0.0195
GV (−1)	1.1690	0.0113	GV (−1)	0.1884	0.0019
ΔGV (0)	1.3821	0.0247	ΔGV (0)	−0.2073	0.0088
			S_2004	−57.3101	0.0398
Auxiliary hypotheses: h_1: reject, *p*-value 0.0152 h_2: reject, *p*-value 0.0247 Supplementary estimations, *p*-values: A normality test: 0.9794 ADF test of residual (without trend): 0.0908 ADF test of residual (with trend): 0.3766 ARCH effect: 0.5300 R-squared: 0.4639 QLR test *p*-value: 0.4771, year: 2005			Auxiliary hypotheses: h_1: reject, *p*-value 0.0052 h_2: reject, *p*-value 0.0088 Supplementary estimations, *p*-values: A normality test: 0.7476 ADF test of residual (without trend): 0.0028 ADF test of residual (with trend): 0.5953 ARCH effect: 0.4847 R-squared: 0.5189 QLR test *p*-value: 0.2251, year: 2007		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

Appendix D

Table A4. NARDL estimations for Estonia after eliminating insignificant variables.

Variable	Coefficient	*p*-Value	Variable	Coefficient	*p*-Value
Using NU and GV:			**Using LU and GV:**		
Constant	−36.7842	0.7742	Constant	306.014	0.0566
ΔGV− (−2)	−2.8366	0.0679	LU (−1)	−0.4200	0.0454
Auxiliary hypotheses: h_2: accept, *p*-value 0.0679 Supplementary estimations, *p*-values: A normality test: 0.0025 ADF test of residual (without trend): 0.0352 ADF test of residual (with trend): 0.4397 ARCH effect: 0.4523 R-squared: 0.1571 QLR test *p*-value: 0.0228, year: 2002			Auxiliary hypotheses: h_1: reject, *p*-value 0.0454 Supplementary estimations, *p*-values: A normality test: 0.0059 ADF test of residual (without trend): 0.2522 ADF test of residual (with trend): 0.4491 ARCH effect: 0.1634 R-squared: 0.1855 QLR test *p*-value: 0.5210, year: 2000		

Source: authors' calculations based on Eurostat [68] and FAOSTAT [69] data, 2022.

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