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The causal nexus between biomass energy consumption and gross domestic production-ARDL approach

Sediqeh Soleimanifard[a]

[a]Department of Food Science and Technology, College of Agriculture, University of Zabol, Zabol, Iran, 98613-35856

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Abstract

One of the most important economic goals of countries is fostering more economic growth; this involves the increasing usage of energy sources. Because of the limitations in non-renewable energy sources and environmental pollution caused by burning these sources, renewable energy sources have become a priority. Biomass energy is one of the new and renewable varieties of energy. This energy is more compatible with nature and environment, and its production and supply cause little environmental pollution; also, since such energies are renewable, there is no near end for their exhaustion. Therefore, biomass energy constitutes a remarkable part of the world energy supply. Because of the importance of energy in economic growth, this study analyzed the relationship between biomass energy consumption and gross domestic production (GDP) during the 1967-2019 time period, using the auto-regressive distributed lag modeling approach (ARDL) and

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1. Introduction

Energy is one of the valuable sources of nature. Man has continuously made an effort, in various ways, to utilize available energies in order to perform his activities with more ease, along with the lowest cost and highest speed. As the world population is increasing, if the current pattern of

*Corresponding author
Email address: s.soleimanifard@uoz.ac.ir (Sediqeh Soleimanifard)

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energy use does not change, energy consumption will also increase. Supplying clean, renewable and economic energy is regarded as one of the necessities of the world's economic systems. Oil and its derivatives are among the valuable national and vital sources of our country; the non-optimal usage of these sources can, however, sometimes cause irrecoverable damages. Therefore, specialists are looking for sources to serve as good substitutes. On the one hand, fossil fuels create numerous types of ecological pollution. Specialists believe that using clean energy instead of energies derived from fossil fuels can prevent ecological pollution and dangers caused by it. One of these clean energies is biomass energy. Biomass energy comprises the produced energy of all waste and garbage obtained from living beings, with the highest energy potential after solar energy. Currently, the highest share of renewable energies is obtained from biomass, which is because of its special advantages, such as economy, environmental friendliness, dispersion and easy access. A scientific definition of biomass considers this energy as constituting all degradable materials obtained from agricultural, forest and livestock activities, as well as those derived from urban and industrial solid and liquid waste. Using biomass to produce energy is of importance for many reasons. Biomass resource materials can meet the need of different sections in the human society using an original form of energy, such as power or energy carriers, and gaseous and liquid fuels; this distinguishes biomass energy from other new energies. Biomass is a type of energy related to a group of products obtained from photosynthesis, such as jungles, parts of plants and leaves, ocean organisms, animal waste, food waste, etc. Each year, an amount of solar energy, which is several times more than the annual consumption of world energy, is stored in leaves, trunk and branches of trees through photosynthesis. Therefore, in regard to storing solar energy, biomass is unique among renewable energy resources. Biomass energy is consumed directly or indirectly. Direct consumption is the traditional way to apply biomass energy, which includes heating, cooking and industrial procedures. Indirect consumption or modern consumption is one of the most advanced stages of converting biomass energy to secondary energies. During urbanization, along with industrialization and economic growth, the energy transfer from biomass traditional energy consumption to fossil fuels energy consumption has been speeded; so the penetration of such fossil fuels to the countries' commercial usage has led to the decrease of biomass energy traditional consumption. In addition, the effects of industrialization and oil crisis from 1974 to 1976 led to the transfer of energy from modern fossil fuels to the modern biomass energy. Since biomass energy is abundant and available; it decreases the overseas dependency on oil due to its renewability. In addition, biomass energy can be converted to beneficial thermal energy, electricity and fuel for the purpose of transfer.

In developing countries, modern biomass energy can also serve as a basis for providing rural employment and income. Since biomass production is a complicated task, producing raw materials can be an important source for basic employment and additional income in different rural areas. Social and economic advantages of biomass energy consumption work as a driving force t promoting the role of biomass energy share in the total energy supply portfolio. In general, the economic effect of biomass energy production and consumption is analyzed for three social-economic indexes including gross production, employment and value added. Therefore, the input-output table is used to analyze the economic effects; this table has been designed for estimating the relationship between the initial effect of change in demand and its effect on the total changes. This study, due to the important role of biomass energy in economic growth and the struggle with energy crisis, examined the relationship between biomass energy consumption and economic growth in Iran; this was done using the auto-regressive distributed lag modeling approach and causality tests during the 1967-2014 period. This paper is organized in seven sections; after introduction, section two is dedicated to a review of the theoretical foundations. Then, some of the previous research is presented in section three; in sections four and five, in addition to introducing the research data, the research method and study model have also been presented. Finally, data analysis and conclusions drawn according to the conducted tests are presented in sections six and seven, respectively.

2. A review of the theoretical literature

Four hypotheses have been presented on the relationship between energy use, economic growth and production variables in the literature related to macroeconomics. The first hypothesis is known as the Growth Hypothesis; according to this hypothesis, energy is considered as one of the important agents of production along with labor force in the production process, and the increase in energy consumption can promote the economic growth and production levels. Therefore, in this scenario, energy limitations and conservation policies can have a reverse effect on the gross domestic production (GDP) and economic growth. The second hypothesis corresponds to Conservation Hypothesis, suggesting some energy conservation policies to reduce its consumption and to ensure that wastes would have no adverse effects on the production and economic growth, helping to boost it. In other words, this hypothesis is accepted only if the actual GDP increase leads to the enhanced energy consumption. The Neutrality Hypothesis is another hypothesis related to the relationship between energy consumption and production, showing that energy consumption has a low and insignificant effect on production. So, this hypothesis is accepted only when there is no causal relationship between energy consumption variables and gross domestic production (GDP). Belloumi (2009) believes that the major reason for the neutrality of energy effect on the economic growth is that the cost of energy can be ignored and it does not seem to have any significant effect on the economic growth [6]. Also, it has been argued that the possible effect of energy consumption on economic growth depends on the economic structure and the country's economic growth level. When the economy is developed, the production structure is diverted towards the service sections not much dependent on energy. Feedback Hypothesis is the fourth hypothesis considering the relationship between energy consumption variables and gross domestic production (GDP) and economic growth. Based on this hypothesis, energy consumption and gross domestic production (GDP) have a reverse relationship, complementing each other. Therefore, if there is a bilateral causal relationship between these two variables, then this hypothesis cannot be rejected and the enhancement and improvement of energy consumption policies can serve as the basis for the increase in the production level, thus contributing to economic growth [2, 15, 16]. After stating the presented assumptions on the relationship between energy consumption and gross domestic production (GDP), in order to further analyze the relationship between these two variables, we will discuss the views of some economists. Some economic experts such as Berndt and Wood (1975), regarding the subject of energy, argue that energy is an agent of production in the total production function, and that it has a separable and weak relationship with the labor force [7]. Their suggested production function is Q-f [G (K,E), L]. They believe that energy and capital are mixed together, producing the G production agent; then they are mixed with labor in order to produce a given product. Therefore, labor is mixed with G, not with capital and energy, separately. On the other hand, some economists believe that energy in nature exists in a fixed amount; it is renewable and convertible to matter and it does not disappear. Therefore, in biophysical models presented by Nayer and Ayras (1984), the production of economical goods was found to require the consumption of an abundant amount of energy in production. So, energy was the only and the most important growth factor. Labor force and capital are regarded as the intermediary factors whose application requires energy. Stern and Cleveland (2004) studied the factors that could have an effect on the relationship between energy consumption and economic activities [21]. They presented the general form of a production function, as represented below:

$$(Q_1 \dots \dots Q_m) = f(A.X_1 \dots \dots X_n.E_1 \dots \dots \dots E_p),$$

where Q_i refers to various economic productions, such as produced goods and services, produced inputs such as capital, labor force, etc. E_i refers to different inputs of energy, such as oil, coal, etc. Meanwhile, A is the technological status defined as the overall productivity index of the factors. In this function, the relationship between energy and overall production, including gross domestic production (GDP), can be influenced by some factors, such as switching between energy and other inputs, technological changes, change in the structure of energy and the product made. The change in the combination of other inputs, such as transfer from a user-based economy to a capital one, can also influence the relationship between energy and production. Also, it may affect the variables of productivity inputs of all factors; this is related to studies looking at the collection of technological changes of X. According to the available theoretical foundations, to justify the relationship between energy consumption and GDP, we can, to a large extent, confirm the existence of such a relationship according to the theoretical perspective .

3. Literature review

During recent decades, many studies have been conducted on the Granger causal relationship between energy carriers and macroeconomic variables, especially economic growth. These studies have often led to obtaining different results, which could be attributed to (A) difference in the applied methods, (B) the optimal lag determined for examining the causality for the country under study. Among the most common methods applied in empirical studies, we can refer to causal tests, which are employed to study the relationship between production and energy. Few studies are, however, available on the causal relationship between biomass energy and renewable energies, and the economic growth; despite this, some of them will be reviewed here. Chien and Hu (2007), for example, analyzed the effects of renewable energy on the economic growth for 45 countries during the 2001-2002 period using the Panel Data method. The results showed that the increase in the usage of renewable energies improved technical and economical efficacy, as well as economic growth [12]. Sadorsky (2009) also studied the relationship between consumption of renewable energy, income, oil prices and Carbon Dioxide emissions using the VAR method, from 1980 to 2005, for G7 countries. The obtained results showed that there was no short-term relationship between renewable energy and economic growth [19, 20]. Menegaki (2011) used the Panel Correction Error model to study the causal relationship for energy consumption; also, the multi-variable Panel model was applied for gross domestic production (GDP) in the case of 37 European countries during the 1997-2007 period. In this study, the Granger causality relationship between renewable energies consumption and economic growth, whether in the long- or short-term, was not proved. The results of the research carried out by Menegaki (2011) showed the insignificant role of the consumption of renewable energies in gross domestic production (GDP) [14].

Bildirici (2013) studied the long- and short-term causality between biomass energy consumption and economic growth for ten developing countries using the AEDL method in the 1980-2009 period. There was a weak casual relationship between variables [22]. Further, Bildirici and Ozaksoy (2013) conducted a causality analysis to address the relationship between biomass energy consumption and economic growth by using the ARDL model and VECM models in the 1960-2010 time period for a few selected European countries. Their results showed that there was a unilateral causality from GDP to biomass energy consumption in Australia and Turkey; a unilateral causality between biomass energy consumption and GDP was observed for such countries as Hungary and Poland [10]. Bildirisi (2014) co-integration relationship and causality were studied in regard to biomass energy and economic growth in developing countries using ARDL combination and Data Panel during the 1990-2011 period. Their results showed that biomass energy consumption had a positive effect on economic growth [9].Further, Aslan (2016) addressed the causality relations existing among economic growth, biomass energy consumption, employment and capital in the U.S, during 1961-2011 period; this was done using the ARDL approach. The obtained results illustrated the unidirectional causality from biomass energy consumption to the real GDP [3]. In another study, Bildirici and Özaksoy (2018) addressed the potential relationship existing between biomass energy consumption and economic growth in the case of some European Transition Countries during the 1981–2014 time period; this was done using ARDL and Panel data methods. The results obtained lent support to the presence of some bidirectional causality for all countries [8]. Further, Aydin (2019) investigated the potential relationship that might exist between economic growth and biomass energy consumption in BRICS countries during 1992-2013 period; this was done using panel analysis. According to the obtained results, biomass energy had a positive effect on the economic growth in all countries with the exception of Brazil [4]. The causality relationship between biomass energy consumption and economic growth was investigated by Ajmi and Inglesi-Lotz (2020) in the case of 26 OECD countries based on panel analyses. It was revealed that there was bidirectional causality between biomass energy consumption and economic growth for the 1980-2013 time period [1]. The nexus between biomass energy consumption and financial development was probed by Zeren and Hizarci (2021) for some developing countries in the 1990-2018 time period; this was carried out using bootstrap panel causality tests, panel cointegration with multiple breaks and heterogenous panels. Computational results revealed that BEC and FD had been cointegrated in the long-term and this relationship was positive [25]. Meanwhile, the effect of biomass energy consumption on human development was investigated in BRICS countries during 1990–2015 period; this was done using the LM bootstrap panel cointegration test, as reported by Wang, Bui et al. (2020). It was revealed that the use of biomass energy promoted human development in BRICS countries and the bidirectional causality existed between these two variables [23]. Further, these same researchers (2021) added public debt approach as the mediating variable to their previous work. The obtained results showed some bidirectional causality between human development and renewable energy consumption, as well as between human development and public debt [24]. In another investigation, Gao and Zhang (2021) probed the potential relationship among CO2 emissions, biomass energy consumption, economic growth and urbanization for a panel consisting of 13 Asian developing countries. Their results revealed a long-run equilibrium relationship among all factors mentioned [13]. Determinants of renewable energy consumption, urbanization and economic globalization in Sub-Sahara Africa from 1990 to 2015, urbanization and economic globalization. These works have revealed that urbanization could adversely affect the consumption of renewable energies [5].

4. Data and Econometric Methodology

4.1. Data

For this research, the annual data belonging to the 1967-2019 period, including biomass energy consumption or BEC, gross domestic production, capital and labor force, were extracted from the energy balance sheet and the Central Bank of Islamic Republic of Iran, respectively. In this paper, generalized Dickey Fuller tests, Phillips-Perron and KPSS were applied to study the stationary variables. The null hypotheses in the Dickey Fuller test and Phillips- Perron indicate the existence of a single root in a series. As can be observed from table (1), some variables have the null stationary I(0), while some others have the one I(1) stationary. In order to estimate the model, Eviews 7 and Microfit 4 software were used. After conducting the single root test, in the next stage, the short-term relationship between variables was studied by the F and W test and long-term coefficients were counted. In the next stage, the Error Correction Model was employed to study the short-term relationship and the augmentation speed of the long-term balance was obtained. Finally, CUSUM and CUSUMSQ tests were conducted in order to ensure the validity of the obtained coefficient in time.

4.2. Econometric methodology

In this empirical study, we used the ARDL Co-integration method presented by Pesaran et al (1999) to study the relationship between variables. ARDL Co-integration approach is valid, even in small samples; however, as in other Co-integration models, it is not sensitive to sample size. Also, in this method, there is no need for all variables to be I(1). However, it should be noted that no variable should be I(2). It is because in this method, critical values shown with the assumption of I(0) and I(1) in variables and if there is no variable between variables, that is I(2), these critical values may not be correct; thus, the test may have no validity [17]. The co-integration process in the ARDL approach constitutes two stages.
The first stage, the existence of a long-term relationship between research variables consistent with Equation (4.1) is studied.

$$\Delta GDP_t = \alpha_1 + \sum_{i=1}^{p} \varphi_{1i} \Delta GDP_{t-1} + \sum_{j=0}^{q} \beta_{1j} \Delta BEC_{t-j} + \delta_1 GDP_{t-1} + \delta_2 BEC_{t-1} + \varepsilon_{1t} \tag{4.1}$$

ε_{1t} and Δ are the white noise and indexes of the first order differences, respectively. ARDL model estimates $(p+1)^c$ regression to choose the optimal lag of each variable (P is the maximum number of lags and c is the variables available in the model). Also, the optimal variables' lag was chosen based on Akaike criterion (AIC). This method has many advantages in contrast to other common techniques; therefore, it has a broad usage in the empirical studies. The most important advantage of the ARDL approach is that this method, regardless of having variables of the I(0) or I(1) model, is applicable. Another reason is that this method has more applicability in small or limited samples, in contrast to other methods. Also, in this method, in addition to counting the long-term relationships between variables, counting the dynamic and short-term relationships is also possible. Further, the regulation speed in long-term balance after short-term shocks is accountable by adding the ECM model. In addition to this problem, inbreeding, due to the lack of correlation disruption, does not occur in the ARDL approach [17]. The first step in estimating the ARDL model is to study the existence of a long-term relationship between all variables of the model , as conducted by utilizing the F Test or Wald test. In this test, the null hypothesis, indicating that there is no long-term relationship between variables and the opposite hypothesis, points to the existence of a long-term relationship between variables, as defined below:

$$\left\{ \begin{array}{l} H_0 : \delta_1 = \delta_2 = 0 \\ H_1 : \delta_1 \neq \delta_2 \neq 0 \end{array} \right\}$$

F and W statistics obtained were compared with two critical values; the low values assume that all variables are I(0), while the higher ones postulate that all variables are I(1). If F or W statistics is bigger that the higher limit of the critical value, the null hypothesis, indicating that there is no long-term relationship, is rejected; if the test statistics is lower than the low limit of the critical value, the null hypothesis cannot be rejected; if the statistics were between the low and high limits of critical values, the results would be considered ambiguous [18]. According to Table (2), the marginal test shows the long-term relationship between biomass energy consumption (BEC), gross domestic product (GDP), and capital and labor force. In both F and W statistics, the ECM's negative value is indicative of the existence of a long-term and co-integration relationship between variables.

In the second stage, if the long-term relationship is verified (Rejection of Null Hypothesis), the long-term model of estimation and the model's ratings residing in it are chosen by the Akaike Test (AIC) (Equation (4.2)).

$$GDP_t = \alpha_2 + \sum_{i=1}^{p_2} \varphi_{2i} GDP_{t-i} + \sum_{j=0}^{q2} \beta_{2j} BEC_{t-j} + \varepsilon_{2t} \tag{4.2}$$

The last stage in estimating an ARDL model is studying the short-term relationship between variables and counting the regulation speed of short-term imbalances in each period in order to reach the long-term balance (Model of Equation (4.3)).

$$\Delta GDP_t = \alpha_3 + \sum_{i=1}^{p_3} \varphi_{3i} \Delta GDP_{t-i} + \sum_{j=0}^{q3} \beta_{3j} \Delta BEC_{t-j} + \varphi ECT_{t-1} + \varepsilon_{3t} \tag{4.3}$$

5. Results

According to the coefficients of variables, biomass energy production could be observed in both long- and short-term models in tables (3) and (4), with a positive effect on Iran's economic growth at the significance level of one percent (1%), during the time of the study. According to the table above, capital and labor force had a positive effect on gross domestic production (GDP) in both long- and short-term. If biomass energy consumption is increased by 1%, gross domestic production (GDP) will be raised by 0/56 percent in the long-term. As a result, biomass energy consumption could have a positive effect both in short- and long-term. Auto-integration statistics, correlation, variance heterogeneity, normalcy and function's form, along with diagnostic parameters, for the stable integration of CUSUM and CUSUMSQ of Brown et al (1975) are presented in table (5). As can be observed, there is no auto-integration between variables and variance dissimilarity. Data is normal and the form of equations is according to CUSUM and CUSUMSQ statistics, thus ensuring stability [11].

Although the Co-integration test can determine the existence or non-existence of the Granger causal relationship between variables, it cannot determine the trajectory of the causal relationship. Several tests are used to study the causal relationship between variables. However, some of these tests, like Granger Causality Standard Test and Heshineo's Granger Causality Test, require variables to be stable; otherwise, their validity is declined. In this research, we used Toda and Yamamato's causality test to fix these problems. Toda and Yamato have used a regulated vector auto-regression model to study the causality relationship. In this method, the optimal lag of the Vector Auto-regressive model (dmax+ K) must be specified. In this research, the optimal lag 3 (K=1 and dmax=1) was obtained by equation (5.1).

$$\begin{bmatrix} \ln GDP_t \\ \ln BEC_t \\ \ln Cap_t \\ \ln Lab_t \end{bmatrix} = \mathrm{A}_0 + \mathrm{A}_1 \begin{bmatrix} \ln GDP_{t-1} \\ \ln BEC_{t-1} \\ \ln Cap_{t-1} \\ \ln Lab_{t-1} \end{bmatrix} + \mathrm{A}_2 \begin{bmatrix} \ln GDP_{t-2} \\ \ln BEC_{t-2} \\ \ln Cap_{t-2} \\ \ln Lab_{t-2} \end{bmatrix} + \mathrm{A}_3 \begin{bmatrix} \ln GDP_{t-3} \\ \ln BEC_{t-3} \\ \ln Cap_{t-3} \\ \ln Lab_{t-3} \end{bmatrix} + \begin{bmatrix} \varepsilon \ln GDP_t \\ \varepsilon \ln BEC_t \\ \varepsilon \ln Cap_t \\ \varepsilon \ln Lab_t \end{bmatrix} \tag{5.1}$$

In equation (5.1), $\mathrm{A}_1 - \mathrm{A}_3$ represent four matrix coefficient vectors 4*4, Also A_0 is the intercept matrix of 4*1 and ε, having a normal distribution with zero average and fixed variance. In this model, if we have $\alpha_{12}^1 = \alpha_{12}^2 = \alpha_{12}^3 = 0$ coefficients, we test the hypothesis that biomass energy consumption ($\ln BEC_t$) and Granger causality of economic growth ($\ln GDP_t$) could be observed in the first system's equation in the relation (5.1). The test statistic for testing the null hypothesis was Wald statistics. In addition, we could test the lack of causality relationship of economic growth ($\ln GDP_t$) to biomass energy consumption ($\ln BEC_t$)when the null hypothesis in the second equation of Equation (5.1) was established. Granger causality results are presented in table (6). According to this table, the unilateral causality relationship of biomass energy consumption to economic growth in Iran could be observed, while no Granger causality relationship of economic growth to biomass energy consumption was ever seen.

6. Conclusions

In this study, the co-integration and causality relationship between biomass energy and Iran's gross domestic production (GDP) were considered using the ARDL approach and Toda and Yamamoto,s causality. According to the results obtained, if biomass energy consumption is raised by 1%, gross domestic production (GDP) will be increased by 0/56% in the long-term; meanwhile, if biomass energy consumption is increased by 1%, gross domestic production (GDP) will be raised by 0.02 in the short-term. As a result, biomass energy consumption during both short- and long-term could have a positive effect on the economic growth. The causality results also showed the unilateral causality from biomass energy consumption during both short- and long-term periods in Iran, while no causality relationship of economic growth to biomass energy consumption was observed.

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Table 1: Testing the Stationary Variables

		KPSS		Phillips-Perron		Generalized Dickey Fuller	
		without Trend	with Trend	Without Trend	With Trend	With Trend	With Trend
Biomass Energy		0.49	0.17	-2.77	-3.30	-2.83	-4.05
GDP		0.79	0.21	3.01	0.88	2.42	0.73
Capital		0.83	0.17	2.91	1.12	1.19	-0.49
Labor Force		0.86	0.11	-0.98	-1.29	-0.66	-3.12
The Critical Statistics	1%	0.74	0.21	-3.57	-4.16	-3.57	-4.17
	5%	0.46	0.14	-2.92	-3.51	-2.92	-3.51
	10%	0.35	0.14	-2.6	-3.18	-2.6	-3.18

Source: Research Finding

Table 2: Testing the Long-term Relationship between Variables in the ARDL Model

Statistics Type	Size	95%	95%	Result
F Statistics	13.11	2.41	2.78	Cointegration
Wald Statistics	41.73	8.67	14.49	Cointegration
Ecm(-1)	-0.089(-2.07)			Cointegration

Source: Research Finding

[a] The Breusch-Godfrey LM test statistic for no serial correlation.
[b] The White's test statistic for homoscedasticity.
[c] The Jarque-Bera statistic for normality.
[d] The Ramsey's Reset test statistic for the regression specification error.

Table 3: Results of long-term Coefficients

Dependent Variable	Independent Variable	Estimated Coefficient (t statistics)
GDP	Intercept	-2.43 *** (-3.12)
	Biomass Energy	0.56 *** (4.56)
	Capital	0.29 *** (6.62)
	Labor Force	2.01 *** (5.34)

Source: Research Finding

Table 4: Results of short-term Coefficients

Dependent Variable	Independent Variable	Estimated Coefficient (t statistics)
GDP	Biomass Energy	0.02 *** (2.97)
	Capital	0.44 *** (9.34)
	Labor Force	-2.69 *** (-2.56)

Source: Research Finding

Table 5: Diagnostic tests of short- and long-term equations

Dependent Variable	Tests	LM Version
GDP	Serial Correlation[a]	1.09(0.34)
	Hetero scedasticity[b]	0.47(0.61)
	Normality[c]	0.38(0.79)
	Functional Form[d]	0.07(0.98)
	CUSUM	Stable
	CUSUMQ	Stable

Source: Research Finding

Table 6: Results of Granger Causality Analysis of the relation between Variables

Wald Statistics	GPD → Biomass Energy Consumption		Wald Statistics	GPD → Biomass Energy Consumption	
	Lag ratio	Causality		Lag ratio	Causality
0.65	1	No	6.68	1	Yes