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THE ROLE OF GREEN FINANCE ON RENEWABLE ENERGY, CO2 EMISSIONS AND ECONOMIC GROWTH: EVIDENCE FROM THE EUROPEAN UNION

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Abstract: *Green finance is the main tool used to mitigate the effects of climate change. It is a financial instrument used to stimulate investments and projects within the green energy sector, increase energy efficiency and offset carbon emissions. The objective of this study is to analyze the effects that green finance has on renewable energy, carbon emissions and economic growth by looking at the European Union during 2000-2020. The analysis uses a panel data approach and conducts diagnostic tests in order to assess the presence of heterogenous slopes, cross-section dependence, and co-integration tests in order to examine the relationship between variables. Due to the skewness and variability, the analysis will be conducted using the method of moments quantile regression. The results of the analysis show that there is an unsignificant negative relationship between green finance and economic growth, a positive relationship between green finance and renewable energy and CO2 emissions within the European Union countries.*

1.Introduction

Although there are people around the world that dismiss the existence and validity of climate change and its effects (Chamie, 2023), there is scientific proof that shows the existence of climate change, and that the temperature of the Earth is rising at an alarming rate. The weather conditions exhibit a constant increase in global temperature, especially between the years 2016-2020, increase in ocean's temperature that decreases the amount of ice sheets and glaciers causing a rise in the sea level, an increase in ocean acidity and increase in the frequency and intensity of extreme weather events (NASA, 2023). The main causes of global warming are greenhouse gases which are resulted from human activity. The largest contributor to greenhouse gas emissions is due to the burning of fossil fuel in order to produce energy (IUC, 2000). Despite the expansion of the green energy sector in the EU, its main source of energy is reliant on oil production. From 2010 to 2020 the consumption of fossil fuel decreased by 43% while renewable energy increased by 39.2% (Eurostat, 2022). In order to mitigate the financial risk of investments in green energy and environmental projects, financial activities that involve various financial instruments have been developed. (Liu, et.al, 2021). Green finance can be explained as any financial product, service, investment used in order to reduce greenhouse gas emission, support environmental-friendly and sustainable projects, mitigate and off-set greenhouse gas emissions. Green finance investments can be privately or publicly focused on either protecting natural resources such as water, landscapes and biodiversity or renewable energy (Lindenberg, 2014). Green finance instruments are developed in order to promote green energy and green projects through carbon bonds and markets, community-based green funds, green banks and fiscal policy (Asian Development Bank, 2019).

The aim of this study is to assess the role that green finance has on renewable energy, carbon emission and CO2 emissions in EU during 2000-2020 by looking at environmental taxes. The study uses environmental tax as a proxy measure for green finance, primary energy supply as a proxy for energy intensity and GDP growth, urban population and trade openness in order to assess economic growth. The study also uses CO2 emissions to track the impact that the investments in green energy have on the emissions of each country. The objective of this research is to evaluate the relationship between green finance and CO2 emissions, renewable energy and economic growth. As far as we know there is limited research regarding the role that environmental tax has on renewables, CO2 emissions and economic growth in the European Union. Most studies cannot reach a consensus. Most analysis is using evidence from the Asian countries, BRI region or OECD countries. There are no studies, as far as the author's knowledge, looking at evidence from the EU countries. Since green finance is a new topic, many variables are taken as a proxy for green finance, such as carbon investment, carbon tax, green loans, environmental tax.

The paper is organized as follows: Section 2 provides information on literature review, Section 3 presents the materials and methods used, Section 4 shows the results and discussion, and Section 5 concludes this study and advice on policy implications. Section 6 presents the limitations of the study.

2.Literature review

2.1 The impact of environmental taxes on renewable energy

In the European Union, the dependence and insecurity of oil supply has pushed renewable energy to grow at a higher rate compared to the rest of the economy (Jagerwaldau, 2007). Besides the reliance on oil, the economic conditions caused by the COVID-19 pandemic and ongoing war in Russia and Ukraine have also caused major changes in the renewable energy market. The COVID-19 pandemic has slowed the interest in development of alternative sources of energy (Abbas et al. 2023). While the uncertainty caused by the Russia- Ukraine war has caused the renewable energy market size to increase and attract new investors. (Umar et al., 2022).

Environmental taxes are used as a main tool for mitigating the emission of greenhouse gases by stimulating the usage of alternative sources of energy (Shahzad, 2020). (Dogan et. al, 2022) study based on G7 economies shows that environmental taxes decrease the reliance on the consumption of energy based on natural resources and increases the usage of renewable energy. (Fang et al. 2022) shows that in the countries along the Belt and Road, environmental tax has a negative effect on the usage of renewable energy in the short run. In the long run, an increase of 1% of environmental tax increases the consumption of renewable energy by 1.2%. The Dumitrescu-Hurlin causality test also shows the presence of a two-way causality between renewable energy and environmental taxation. Although (Safi et al. 2021) recommends the usage of environmental tax for policy makers in order to encourage changes in the energy structures of firms and support the usage of regenerable energy, (Lapinskiene et. al, 2016) results show that environmental tax does not promote the use of renewable energy. Same results were concluded by (Dogan et al., 2023) during 1995-2005 in the EU, environmental taxes have a negative impact on the promotion and consumption of renewable energy.

2.2 The impact of environmental taxes on economic growth

It is expected that green taxes are going to support sustainable economic growth and development post-Covid 19 pandemic (European Commission, 2021). There is very few evidence in the OECD countries that environmental taxes promote economic growth, although there is evidence that economic growth facilitates environmental taxes (Abdullah and Morley, 2014). Across 31 European countries, during the period 2009-2019, data shows that environmental taxes in the context of a reform negatively affects economical growth, and that the size of the effect is dependent on the size of the country (Tchapchet-Tchouto et al., 2022). During 1994 and 2013, in the 31 OECD countries, (Hassan et al., 2020) shows that environmental taxes only positively affect the level of economical development in countries with a high initial level of GDP, and that the effect of the environmental taxes on GDP is dependent on each countries' level of development. The research conducted by (Dokmen, 2012) based on 26 European countries contradict the results of the previous studies and concludes that there is a positive relationship between environmental tax and GDP, therefore there is a theoretical possibility that environmental tax can facilitate economical growth although the impact is higher in the short run compared to long run. The discrepancies in the results can be explained by the analysis conducted by (Ono, 2003). Its results show that if the environmental taxation level is situated below an equilibrium point, an increase in the amount of environmental taxation will facilitate economic development. If the amount of environmental taxation is situated above the equilibrium point, the increase in the amount of environmental taxation will negatively affect economic growth.

2.3 The impact green finance on CO2 emissions

(Meo, 2022) conclude that green finance is the most effective strategy for mitigating CO2 emissions. The EU has engaged through the European Deal in reducing greenhouse gas emissions by 55% with the support of green taxes that include the taxes on transportation, pollution and exploitation of resources. The analysis conducted by (Hajek, 2019) regarding the efficiency of environmental tax within the energy sector of 5 selected European countries shows that environmental tax is effective in decreasing GHG emissions and that an increase in tax of 1 euro per ton decreases annual emissions by 11.58 kg. (Woldfe-Rufael and Mulat-Weldemeskel, 2021) conclude that although environmental taxes are not sufficient by itself to reduce the amount of CO2 emissions, they are an effective aid. Contradictory results are concluded from the analysis conducted by (Lapinskiene et. al, 2016) using evidence from the European countries, which shows a positive relationship between environmental taxes and greenhouse gasses, meaning that an increase in the amount of environmental tax increases greenhouse gas emission. (Aydin and Esen, 2018) find that in the EU member states during 1995 and 2003, the environmental taxes have a positive effect on CO2 emissions up to a certain threshold. Any increase in the amount of environmental taxes above the threshold negatively affects the level of CO2 emissions.

3. Material and Methods

The study's aim is to investigate the effect that various factors have on energy intensity by looking at the countries from the European Union over a period of 20 years, from 2000 to 2020.

The research design of this paper follows the panel data analysis proposed by (Wu, 2022). Specifically, this study investigates the role that green finance has on energy intensity, CO2 emissions and renewable energy. The study uses GDP growth (GDP), urban population (UBP) and trade openness (TO) in order to capture economic growth, environmental taxes as a proxy for green finance (GRF), primary energy supply as proxy for energy intensity (EI), output of renewable energy (RE) in order to measure the supply of green energy and CO2 emissions (CO2) in order to track the level of emissions. The specification of each variable and data source are as follows:

Variables	Specification	Data Source
Green Finance (GRF)	**Environmental tax, % of GDP**	**OECD 2000-2020**
GDP (GDP)	**Annual GDP growth as %**	**WorldBank 2000-2020**
Trade openness (TO)	**Trade, % of GDP**	**WorldBank 2000-2020**
Renewable energy output (RE)	**% of total electricity output**	**WorldBank 2000-2020**
CO2 (CO2)	**CO2 emissions from**	**WorldBank 2000-2020**

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	burning fossil fuels / metric tons per capita	
Population growth (PG)	**Population growth %**	**WorldBank 2000-2020**
Energy intensity (EI)	**Primary energy supply / total, million toe**	**OECD 2000-2020**

The model used in the paper is as follows:

GRFit=α1+β1EIit+β2GDPit+β3REit+β4Toit+ β 5UBPit+ β6CO2it +εi

The previous equation has interceptors of the slope α and β's, i's as cross-section indicators and t as time-series indicators. ε represents the error term.

The empirical analysis starts with a descriptive analysis of the mean, median, range, minimum, maximum and normality estimation, in order to gain a better perspective of the normality assumption. To assess the volatility of each variable, the standard error will be calculated. In order to test normalcy, the Jarque and Bera test will be used (Jarque and Bera, 1987), while for cross-sectional dependence (Pesaran, 2004) and slope heterogeneity the (Pesaran and Yamagata 2008) test will be conducted. For determining the presence of a unit root in the panel which assesses the stationary of the time series of data, a 2^{nd} generation unit root test will be employed, Cross-Sectionally Augmented Dickey-Fuller (CADF). The CADF test determines if the mean and the variance of the data varies over time, and it is used due to the presence of cross-sectional dependence within the data set. The results of the analysis exhibit a high chance of a unit root occurring in the variables. Since the variables are non-stationary, testing for long-run stable connection is imperative, therefore the testing will be done using co-integration analysis. Co-integration test selected non-stationary variables in order to assess if there is a long-term relation between variables through tests such as Modified Phillips-Peron, Phillips-Perron and Augmented Dickey-Fuller and Westerlund co-integration test which are employed in this paper. The quantile via moments regression method is used (Machado and Silva, 2019) in the analysis in order to determine what effect the different quantiles of the independent variables have on the dependent variable. This kind of quantile regression is mostly used in studies that have as focus environmental and energy issues. This analysis will also use the Granger panel causality heterogeneity test created by (Dumitrescu and Hurlin, 2012).

Table 1 - Descriptive statistics

Variable	GRF	GDP	EI	TO	RE	CO2	PG
Mean	2.70194	2.365411	54.22939	115.7382	21.95049	7.883595	0.223931
Median	2.58	2.446794	0.644	45.41876	0	2.927077	-3.84767
Min	1.2	-14.8386	348.942	351.132	81.05687	25.6042	2.89096

Max	5.1	24.37045	24.8905	102.2943	15.17692	7.223218	0.269006
Std.dev	0.6506452	3.905471	80.28729	60.44553	20.26006	3.755137	0.854848
Skewness	1.089447	-0.1504	2.283952	1.621228	1.010824	1.945008	-0.17734
Kurtosis	3.954637	8.151723	7.35857	5.766786	2.989933	8.467989	4.703257
Jarque-Bera	0	0	0	0	0	0	0
Observations	416	416	416	416	416	416	416

Source: author

Table 1 offers insight regarding data. It shows the mean, median, minimum, maximum, standard deviation, number of observations, and skewness, kurtosis and Jarque-Bera in order to assess the normality of data. From the results of the table, we can state that the data used in the analysis does not exhibit a normal exhibit a normal distribution.

Table 2 – Slope Heterogenity

Slope Heterogeneity		
	Delta	p-value
	7.286	0
adj.	10.304	0

Note: Significance level is donated by *** for 1%, ** for 5% and * for 10%.

Table 3 – Cross dependence

Cross-Dependence		
	F-test	p-value
	6.191	0

Note: Significance level is donated by *** for 1%, ** for 5% and * for 10%.

Table 2 and 3 provide the results of the slope heterogeneity test and cross-sectional dependence tests. In order to not have bias in the analysis the previously stated tests must be employed within the analysis. For the slope heterogeneity test the p-value is 0, which means that the null hypothesis has been rejected and the slope coefficients are not homogenous. The cross-sectional dependence test also has a p-value of 0 which means that the null hypothesis is rejected, showing that the data is codependent between the panels.

Table 4 - Unit root test

Unit Root Test Intercept and Trend				
	l (0)		l (1)	
	t-bar	p-value	t-bar	p-value
GRF	-2.519*	0.124	-2.245*	0.589
GDP	-2.634***	0.041	-2.241*	0.598
EI	-2.896***	0.001	-2.836***	0.003
TO	-1.234*	1	-1.44*	1
RE	-2.372*	0.339	-2.258	0.565
CO2	-2.802***	0.005	-2.459*	0.196
PG	-1.935*	0.963	-2.686***	0.023

Note: Significance level is donated by *** for 1%, ** for 5% and * for 10%.

Table 4 shows the analysis of a second generation unit root test for the 2 levels, level l(0) and level l(1). At the first level, the only significant variables are environmental tax, trade openness, renewable energy output, and population growth, all variables have negative values. At first difference, all variables excluding energy intensity and population growth are significant. At first difference all the values are also negative. Therefore, the significant p-values within the data set show that there is a high chance of a unit root within the variables to occur, which makes the variables exhibit a non-stationary trend.

Table 5 - Cointegration test

Cointegration tests	**Statistics**	**p-value**
Pedorni Cointegraton Test		
Modified Phillips-Perron Test	6.8347	0
Phillips-Perron Test	-4.1569	0
Augumented Dickey-Fuller Test	-2.4545	0.0071
Westerlund Tointegration Test		
Variance ratio	-0.3429	0.3658

Source: author

Table 5 provides the results of the Pedorni cointegration test which consists of 3 different tests: modified Phillips-perron test, Phillips-perron test and Augumented Dickey-Fuller test, which assess the existence of a panel unit root within the time series. The Westerlund cointegration test takes in consideration the variance ratio in order to assess the long-term relationship of the variables. The modified Phillips-Perron test has a p-value of 0 which shows that the null hypothesis is rejected which means that the time series is stationary and does not display a unit root. The p-value of the Phillips Perron test also supports that the time series is stationary without a unit root, and the mean and variance are constant over time. The same conclusion is supported by the results of the Augmented Dickey-Fuller which has a p-value less than .05. The consensus between the previous tests allows for a more accurate analysis and interpretation of the variables. The variance ratio that has a p-value higher than 5% shows that the alternative hypothesis has been rejected and the time series are cointegrated, therefore the time-series exhibits a long-term relationship.

Table 6 - Estimates of quantile regression- MMQR

Variable	**Quantile regression MMQR**											
	location	p-value	scale	p-value	q0.25 coeficient	p-value	q0.50 coeficient	p-value	q0.75 coeficient	p-value	q0.90 coeficien1t	p-value
GDP	-0.022	0.009	-0.007	0.218	-0.016	0.029	-0.021	0.009	-0.027	0.015	-0.035	0.034
EI	-0.002	0	-0.001	0	-0.001	0	-0.001	0	-0.002	0	-0.004	0
RE	0.0034	0.055	0.001	0.33	0.002	0.122	0.003	0.056	0.004	0.71	0.005	0.111
PG	0.039	0.334	0.012	0.668	0.028	0.409	0.037	0.332	0.048	0.375	0.061	0.446
TO	-0.001	0.117	-0.000	0.189	-0.000	0.372	-0.000	0.136	-0.001	0.097	-0.002	0.103
CO2	0.010	0.247	-0.002	0.698	0.0128	0.101	0.011	0.197	0.008	0.462	0.006	0.729
cons	2.838	0	0.603	0	2.300	0	2.725	0	3.258	0	3.919	0

Note: GFR is the dependent variable. Significance level is donated by *** for 1%, ** for 5% and * for 10%.

Table 6 shows the values resulted from the quantile regression with 4 quantiles (25% 50% 75% and 90%). Compared to OLS, the quantile regression shows the effect that green finance has on

GDP, energy intensity, renewable energy, population growth, trade openness and CO2 emissions across different parts of the distribution. In the 25% percentile we notice that green finance has a significant impact on renewable energy, population growth, trade openness and co2 emissions. The change in $1 in green finance will increase renewable energy by .2%, population growth by 2%, decrease trade openness by .4% and increase CO2 emissions by 1.28%. In the 50% percentile green finance has a significant impact on renewable energy, population growth, trade openness and CO2 emissions. An increase in $1 of green finance increases renewable energy by .3232 %, population growth by 3.75%, CO2 emissions by 1.1088% and decreases trade openness by .08%. For the 75% and 90% quantiles green finance has a significant impact on the same variables as it did in the 25% and 50% quantiles, renewable energy, population growth, trade openness and CO2 emissions. In the 75% quantile an increase of $1 in green finance increases renewable energy by .0043, population growth by .04834, CO2 emissions by .0089 and decreases trade openness by .0014. In the 90% quantile an increase in $1 in green finance increases renewable energy by .0056, population growth by .061688, CO2 emissions by .0062 and decreases trade openness by .00203. The table also presents a negative relationship between green finance and economic growth, although it is not significant.

Table 7 - MMQR + Robustness

Variable					**Quantiles robustness**							
	location	p-value	scale	p-value	q0.25	p-value	q0.50	p-value	q0.75	p-value	q0.90	p-value
GDP	-0.02256	0.004	-0.00731	0.158	-0.01604	0.04	-0.02118	0.005	-0.02765	0.004	-0.03566	0.01
EI	-0.00217	0	-0.00107	0	-0.00122	0	-0.00197	0	-0.00292	0	-0.00408	0
RE	0.003461	0.019	0.001213	0.164	0.00238	0.085	0.003232	0.023	0.004305	0.017	0.005632	0.026
PG	0.039864	0.27	0.012189	0.532	0.028999	0.451	0.037567	0.296	0.048349	0.226	0.061688	0.243
TO	-0.001	0.16	-0.00058	0.219	-0.00048	0.465	-0.00089	0.189	-0.0014	0.116	-0.00203	0.116
CO2	0.010626	0.182	-0.002	0.691	0.012814	0.067	0.011088	0.137	0.008917	0.411	0.006231	0.708

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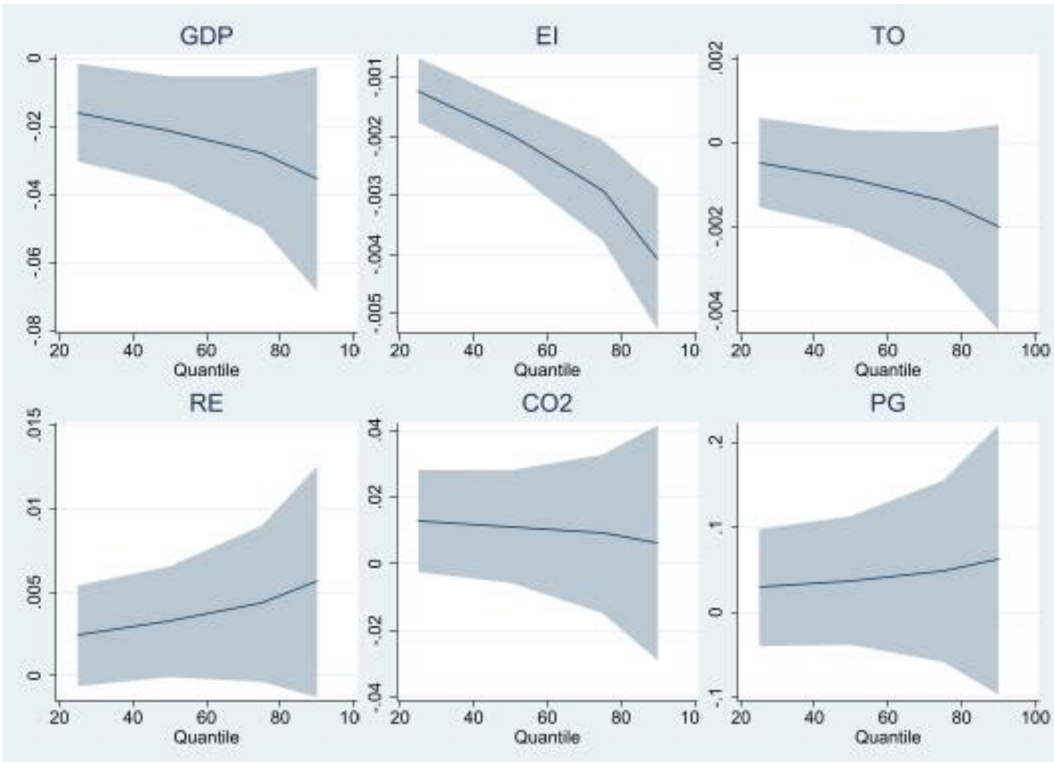

			45									
Cons	2.83 8772	0	0.603 515	0	2.30 0807	0	2.72 5044	0	3.25 8896	0	3.919 322	0

Note: GFR is the dependent variable. Significance level is donated by *** for 1%, ** for 5% and * for 10%.

Table 7 shows the values of robustness analysis of the quantile analysis which is similar to the table 6 analysis, only that it takes in consideration the robustness of the outliers. The variables that exhibit significance are like the ones in table 6 with a small difference. Renewable energy is significant only for the 25% quantile while it does not exhibit significance for the 50% 75% and 90 % quantile.

Figure 1 – Graphical representation of MMQR

Table 8 - Dumitrescu – Hurlin Panel Causality

	WaldStats	Zstats	p-value
GRF=GDP	1.618	2.2284	0.303

GDP= GRF	2.0965	3.9535	0.154
GRF=EI	3.1283	7.818	0.022
EI= GRF	3.7307	9.8457	0.018
GRF =PG	2.1661	4.2045	0.268
PG=GRF	1.9397	3.3881	0.284
GRF=TO	2.737	6.2629	0.11
TO=GRF	2.8195	6.5602	0.149
GRF =CO2	2.8811	6.7825	0.12
CO2= GRF	3.7011	9.739	0.018

Table 8 shows the results of the Dumitrescu- Hurlin Panel Causality test which is used in order to study the casual relationship between two variables. The only pairs of variables that indicate the presence of causality are GRF=EI, EI=GRF, and CO2=GRF, which means that the change in green finance can predict the changes in energy intensity, changes in energy intensity can predict changes in green finance and changes in the level of CO2 emissions can predict changes in green finance.

5. Conclusion and policy implications

The aim of the study is to assess the impact that green finance proxied by environmental tax has on renewable energy, CO2 emissions and economic growth. The point of this paper is to add value to previous literature that has not reached a consensus. The study uses the 27 European Union countries with data from 2000-2020. The analysis conducted using various tests and employs a quantile method of moments regression shows that green finance has a negative effect on trade openness and a positive effect on renewable energy and CO2 emissions. The effect of environmental taxes on renewable energy increases in the higher quantiles while the impact that it has on CO2 emissions decreases in the higher quantiles. The Dumitrescu – Hurlin Panel Causality shows that the changes in CO2 emissions can predict the changes in environmental tax. The same analysis also shows that changes in energy intensity can predict changes in environmental tax and vice versa. Looking at economic growth, we can state that environmental tax does not support it or facilitates it.

As for policy implications, it is recommended that policy makers continuously re-evaluate the equilibrium of environmental taxes so that it can have the most efficient effect on renewable energy and CO2 emissions. Besides the continuous re-evaluation of the necessary level of environmental tax, policy makers can make sure that the revenue gathered is efficiently used in order to promote green initiatives and support R&D. By supporting R&D there is a higher chance of a positive relation between environmental tax and economic development to occur. Due to the negative effect that environmental tax has on trade openness, the implementation of a border carbon adjustment tax in order to promote the usage of green energy in each country's competitiveness could help. It will be useful for the policy makers to explore the alternatives of environmental tax and the trade-offs of it.

6. Limitations

One of the limitations of the study is the availability of data and missing values. The missing values of this study have been cleared; therefore, the data might present bias results. Another limitation that could lead to bias results could be the usage of environmental tax as a proxy for green finance and the usage of panel-data which could offer bias results in the regards of green finance efficiency.

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