



# Output, renewable and non-renewable energy consumption and international trade: Evidence from a panel of 69 countries



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## ABSTRACT

This paper uses panel cointegration techniques to examine the causal relationship between output, renewable and non-renewable energy consumption, and international trade for a sample of 69 countries during the period 1980–2010. In the short-run, Granger causality tests show that there is a bidirectional causality between output and trade (exports or imports), a bidirectional causality between non-renewable energy and trade, and a one way causality running from renewable energy to trade. In the long-run, a bidirectional causality between renewable energy and trade, is noticed. Our long-run ordinary least squares (OLS), fully modified OLS (FMOLS) and dynamic OLS (DOLS) estimates suggest that renewable, non-renewable energy consumption and trade have a positive and statistically significant impact on economic growth. Our energy policy recommendations are the following: *i*) any non-renewable energy policy should take into account the importance of international trade, *ii*) more renewable energy use should be encouraged by national and international competent authorities in order to increase international economic exchanges and promote economic growth without harming the environment, and *iii*) increasing trade is a good vehicle for renewable energy technology transfer and contributes to increase renewable energy consumption in the long-run, thus contributing to reducing greenhouse gas emissions.

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## 1. Introduction

This paper investigates the interaction between international trade and renewable and non-renewable energy consumption by considering a panel of 69 countries. This investigation is interesting because the causal relationship between renewable and non-renewable energy and international trade has not been previously studied. Nevertheless, it is admitted that the use of renewable energy is greatly influenced by technology transfer, which mainly operates through international economic exchanges. The Rio and Johannesburg conferences recognize that trade helps to achieve more efficient allocation of scarce resources and facilitates the access of rich and poor countries to environmental goods, services and technologies [40].

Several empirical studies analyze the causal relationship between economic growth and consumption of renewable energy [3–6,31]. Other research papers analyze the causal relationship between economic growth, renewable energy consumption and carbon dioxide (CO<sub>2</sub>) emissions [7,8,23,30,34]. All these studies agree that renewable energy consumption plays an important role in increasing economic growth and vice versa. Moreover, an energy policy to increase the share of renewable energy in total energy consumption is very effective in reducing greenhouse gas emissions. In addition to capital, labor, and renewable energy consumption, other variables such as international trade can be incorporated into the production function to explain the growth of gross domestic product (GDP).

Many studies investigate the causal relationship between energy consumption (total energy use), international trade, and output. Lean and Smyth [20] study the dynamic relationship between economic growth, electricity production, exports and prices in Malaysia. Granger causality tests show the existence of a unidirectional causality running from economic growth to electricity production. Lean and Smyth [21] study the causal relationship, in

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Malaysia, between output, electricity consumption, exports, labor, and capital in a multivariate model. They show the existence of a bidirectional causality between output and electricity consumption. They conclude that Malaysia should adopt the strategy of increasing investment in electricity infrastructure and encouraging electricity conservation policies to reduce unnecessary use of electricity. Similarly, Narayan and Smyth [24] find feedback effects between electricity consumption, exports and GDP, for a sample of Middle East countries. Sadorsky [32] uses panel cointegration techniques for 8 Middle East countries to study how trade can affect energy consumption. He finds a Granger causality running from exports to energy consumption and a bidirectional causality between imports and energy consumption in the short-run. In the long-run, he notices that an increase in both exports and imports affect the energy demand. In another paper, Sadorsky [33] confirms the long-run causality between trade and energy consumption using a sample of 7 South American countries. He concludes that environmental policies made to reduce energy consumption will reduce trade.

Ben Aïssa et al. [9] explore the relationship between renewable energy consumption, trade and output for 11 African countries. They show that there is a bidirectional causality between output and trade (exports or imports) in both the short and long-run. However, in the short-run, these authors find that there is no causality between output and renewable energy consumption and between trade and renewable energy consumption. The present paper differs from that of Ben Aïssa et al. [9] by the inclusion of non-renewable energy consumption as a dependent variable, and by considering another panel of countries.

To our knowledge, no research has been reported on the causal relationship between international trade, renewable and non-renewable energy consumption. The aim of this paper is to explore the causal relationship between renewable energy consumption, non-renewable energy consumption, trade, and output by considering a panel of 69 countries.

This study has the following structure. Section 2 gives an idea about the renewable energy sector and international trade. Section 3 describes the methods used. Section 4 deals with the results and their discussions. Finally, Section 5 presents the main conclusions and policy implications.

## 2. Renewable energy and international trade

According to the International Energy Agency [18], more than 70 countries are expected to use renewable energy technologies in the power sector by 2017. One policy driver is environmental concerns which aim to reduce CO<sub>2</sub> emissions and local pollutants. Renewables are also encouraged to stimulate economies, reinforce energy security and diversify energy consumption. Renewable energies have been used principally by the electricity sector, followed by biofuels. In most cases, fiscal incentives and/or subsidies are needed because, compared to the use of conventional energy sources, the use of renewable energies necessitates an initial investment cost.

Renewable energy use, including traditional biomass, was 1684 million tons of oil equivalent (Mtoe) in 2010 representing 13% of total primary energy use [18]. This share has remained stable since 2000, but the contributions of different renewable sources have changed. The share of traditional biomass in total renewable energy decreased from 50% in 2000 to 45% in 2010, while biofuels made an increasing share in the transportation fuel needs. The share of hydropower, the largest source of renewable electricity, remained stable. The most important increases are those of electricity generation from wind which increased by 27% and solar photovoltaic (PV) which increased by 42% per year on average during the period

2000–2010. The renewable sector has been affected by the international economic crisis and by the reduction (or suppression) of government's support in some developed countries. However, weaker performances in some regions in Europe and United States for example, have been largely offset by an important increase in the rest of the world, notably in Asia.

Because of governments support, decreasing costs, CO<sub>2</sub> pricing in some regions, and rising fossil fuel prices in the long-term, the International Energy Agency [18] estimates that the share of renewables in primary energy use will increase. Electricity generation from renewables will approximately triple from 2010 to 2035, attaining 31% of total production. In 2035, hydropower will provide half of renewable production, wind nearly one-quarter and solar PV 7.5%. Solar PV production will increase 26-fold from 2010 to 2035. The use of renewables is expected to reduce CO<sub>2</sub> emissions by over than 4.1 Gt in 2035, contribute to the diversification of the energy sources, reduce oil and gas import bills, and decrease air pollution.

The United Nations Environment Program and the World Trade Organization [37] consider that the 60 years prior to 2008 have been marked by a considerable expansion of international trade. In terms of volume, world trade is approximately 32 times greater now than it was in 1950. The share in total GDP increased from 5.5% in 1950 to 21% in 2007. This considerable expansion in world trade has been encouraged by technological progress, which has considerably reduced the costs of transportation and communications, and by countries' use of more open trade and investment policies. The number of countries participating in international trade has increased. For instance, developing countries have approximately doubled their share in international trade in the last 60 years.

This expansion in international trade poses questions about its impact on greenhouse gas emissions. The impact of trade on pollution can be explained by three principal effects, which are the scale, composition and technique effects. International trade can be used as a channel for diffusing technologies, especially from developed to developing countries, to combat climate change. International trade can increase the availability of goods and services that are more energy efficient. The increase in income made possible by trade openness can lead to a demand for better environmental quality and a reduction in greenhouse gas emissions.

It is admitted that international trade and renewable energy consumption are linked. International trade can induce more renewable energy use, for many reasons: *i*) more trade in goods necessitates more energy and renewable energy use to produce and transport these goods from one country to another, *ii*) because of economies of scale and technology progress, the price of equipments (for instance solar PV and onshore wind power) used to produce renewable energy have considerably reduced pushing companies to explore new markets. This makes renewables more affordable for a larger range of consumers throughout the world [35], and *iii*) international trade can play a significant role in greening the energy sector as it is an important vehicle for renewable energy technology transfer. Indeed, international technology transfer through trade occurs when a country imports capital goods, such as machines and equipment, to produce renewable energy. Local firms of the importing country can acquire knowledge, through training sessions for engineers and technicians operating the production line, as customer or distributor, or through business relationships with the source company. As an example, international trade of manufacturing equipments is an important factor, like the low labor cost factor, that have enabled China to acquire foreign technologies to create a domestic PV industry [10]. Consequently, China is the largest solar PV cell producer in the world, with more than one third of worldwide

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