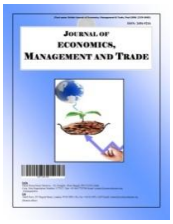

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Formation Mechanism of the Perfect Inverted V-Shape CO2 Emission Amount Environmental Kuznets Curve (EKC) at the Country Level: Taking Taiwan as an Example

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The reduction of carbon emissions (such as CO_2) is important to slow down global warming. The direct emissions of CO_2 in Taiwan are contributed from the power generation sector. This research thus analyzes the effect of fuel used in the past years and finds that the summarized percentage of coal and natural gas used is the key factor in the amount of CO_2 emissions. Results show that the CO_2 emission amount exhibits a perfect inverted V-shape environmental Kuznets curve (EKC) from 1998 to 2014 in Taiwan. We attribute this to there being a disproportion process of transferring residual load powering to base-load powering for coal and natural gas energies and the increase in electric generation amount every year. This disproportion process means the co-existence of all technical generation in power plants.

Keywords: EKC; CO2 emission; disproportion process; coal; natural gas.

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1. INTRODUCTION

The Environmental Kuznets curve (EKC) was proposed from the aspect of the income-driven action upon the environment [1,2] Stern, 2004; [3,4,5]. From the 1985 to 2015 data in Taiwan, the primary energy consumption-to-GDP ratio (called energy intensity) exhibits an EKC pattern (an inverted U-shape of primary energy consumption along with an increase in GDP). In our previous study the turning point of EKC is driven by an exogenous event to an endogenous policy in Taiwan [6]. The reduction of carbon emissions, particular CO_2, is important for slowing down global warming.

Most studies on CO_2's EKC pattern have used cross-country/site [7] and cross-county data [8,9], with a few focusing on a single country [10,11]. The data from a single country are averaged results and can reflect the efficiency of that country's environmental policy. Our EKC research goal is to understand the process for seeking how the formation of the EKC pattern can be driven through policy action for the CO_2 emission issue. It still remains a big challenge throughout the world. From the very few successful formation of the completed CO_2 emission EKC pattern in UK, France, Germany and USA for a related short-run period from 1960 to 2015 [10,12,11]. Here, we define the perfect EKC pattern as an inverted "U". It includes two parts: the half upward curve and the half downward curve.

Among those four cases, the most completed EKC pattern is the UK's CO_2 emissions spanning a total of 250 years [10]. The authors have attributed the success in the UK to its energy structure; i.e., the reduction of coal energy used. If we can find the detailed formation mechanism of such a process, then we may present a feasible process to archive the slowing down of global warming by developing a low carbon economy in every country by transforming this process to each one's own unique social regulation on CO_2 emission reduction. In addition, we also want to understand why the cross-country data can present a completed EKC pattern, as every country has a diverse culture and its own unique social regulation logic. The willingness to reduce fossil fuel use as a governing force is the most important, however, the stability of the electricity system is essential for every country. If the cross-country EKC is simply related to electric consumption and this demand is simply related to industrial production, then this is the core issue for the development of a low carbon economy. Every country knows that low CO_2 emissions are good, but the key is to how to successfully achieve this without harming the economy.

2. METHODS

Many countries have chosen the strategy to decrease CO_2 emissions through by the fuel of fire powered plants from nuclear to coal and flowing to coal and natural gas in Fig. 1. Our study provides a causal explanation for why incompliance in the formation of environmental Kuznets curve (EKC) of CO_2 emissions is in perfect inverted "V" shape in Taiwan.

In Taiwan the amount of CO_2 emissions is in half incompliance in the formation of a strong environmental Kuznets curve (EKC). The direct CO_2 emissions in Taiwan are contributed from the power generation sector in Fig. 2. This paper analyzes the effect of fuel used in the past years and finds that the summarized percentage of coal and natural gas used is the key factor for CO_2 emissions in Fig. 3. We propose an electric system generation evolution in Fig 5. The fuel used for power plants between 1970 to 2015 comes from oil, nuclear, coal, and natural gas. If each technical generation has a clear drop, then the CO_2 emission amount will be stepwise due, because nuclear energy does not emit CO_2 gas. This is called the "proportion process" in Fig 5. If each technical generation co-exists, then it will exhibit continuous growth in CO_2 emission. This is called the "disproportion process" in Fig 6.

Ever since 2006, the summarized percentage of coal and natural gas used has been maintained at 70%, and therefore the CO_2 emission amount is the same. We attribute this trend to the disproportion process Fig 6 of transferring residual load powering to base-load powering for coal energy. In Taiwan, before coal was used as base-load powering, oil energy was used, and after that it was nuclear energy. The CO_2 emissions have rapidly increased since 1990, which matches what has happened in other countries [12].

The EKC pattern is normally an "inverted U" or an "inverted V". We state in the previous section that the inverted U-shape EKC has two curves: one is an upward stage and the other is the downward stage. For an inverted V-shape, we have two slopes. One curve or slope represents one process. In the upward stage, we conclude it

means the disproportion process of nuclear and coal powering fuel for the upward stage in the V shape and the disproportion process of coal and natural gas powering fuel for downward stage in the V shape of EKC.

3. RESULTS AND DISCUSSION

The CO_2 emission amount growth rate approached a plateau at 2006, as in Fig. 3 This means the CO_2 emission amount is maintained if the base-load powering is from coal energy. From those results, we conclude that the CO_2 emissions' upward stage of EKC will form only when the coal total consumption amount is being increased at a constant rate that is not related to the used percentage of coal energy in Fig. 3. In Fig. 4 shows the CO_2 emission EKC in Taiwan from 1995 to 2015. For one tail hypothesis testing, we used the 5% significance level, and then the rejected null probability (Z^*) is < 1.65. Here, the choice value (H0) is set as 15, and the observed averaged value (x) to be 16 between 1998 to 2014, with a standard derivation of "s" years. The Kuznets infrastructural investment cycle has been estimated at 15 to 25 years, and in this paper we choose the minimized value of 15 years. If H0 is not rejected, then the not rejected null probability (Z) must be equal to or larger than Z^*, therefore Ho can equal to x, and the calculated s is < 2.267 years. From Fig. 4, the observed value of s is 2 years, just meet the calculated value. Therefore, the CO_2 emission data for 1998-2014 are suitable for an EKC investigation in the following sections, and this period also matches the change trend of coal used percentage in Fig. 1.

From this fact, the coal used percentage data show a complete EKC pattern, while the CO_2 emission data exhibit a perfect V-shape, which is composed by an upward and a broken downward EKC. The reason for this is due to the disproportion process of coal and natural gas in Fig. 2. Currently, the biggest challenge is that coal energy is the base load power, which means that we have to perform the disproportion process on coal energy beginning in 2021, just like that for nuclear energy in 1986. After 2025, the natural gas energy will be the base load power in Taiwan, and the coal energy will become the most important residual power. However, the electric consumption amount is increasing 2% per year. The increment amount is contributed from natural gas since 1995 and will be a long-run national energy policy up to 2035 in Taiwan. This long-run electric policy is largely different from that of the UK, Japan, and South Korea, in which nuclear energy is still used as the most important residual load power besides using natural gas as the base load power.

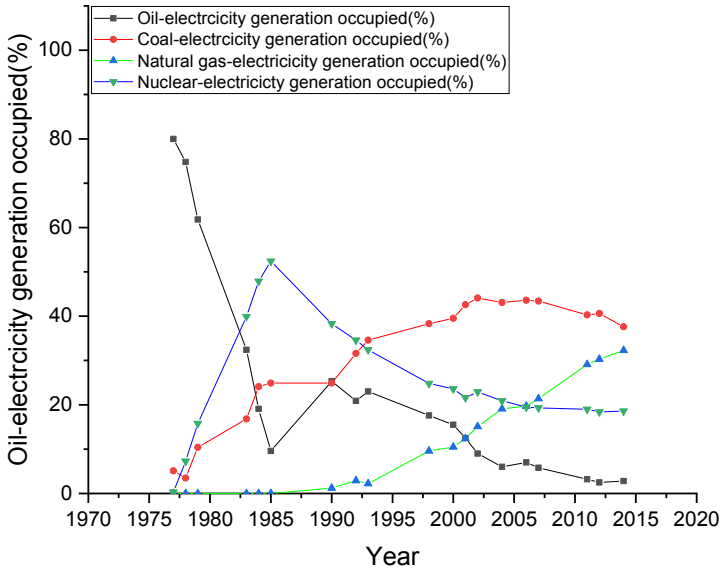

Fig. 1. Electricity generation from various primary energy sources in Taiwan from 1977 to 2014

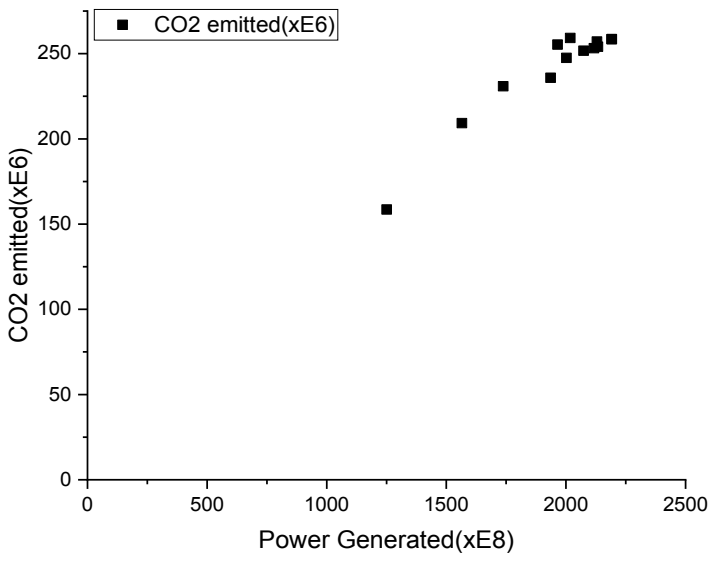

Fig. 2. Power generation and CO_2 emission amount in Taiwan from 1995 to 2015

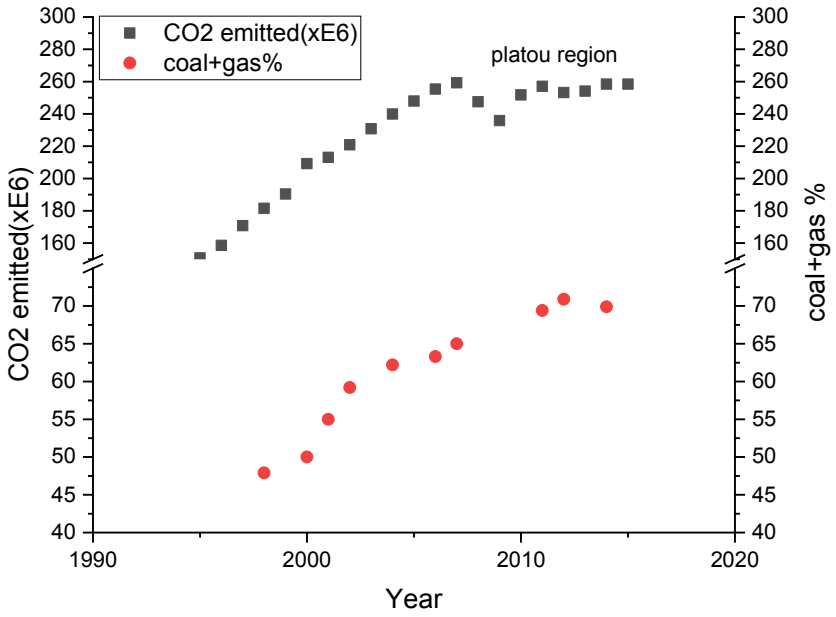

Fig. 3. Summarized coal and natural gas used percentage and CO_2 emission amount in Taiwan from 1995 to 2015

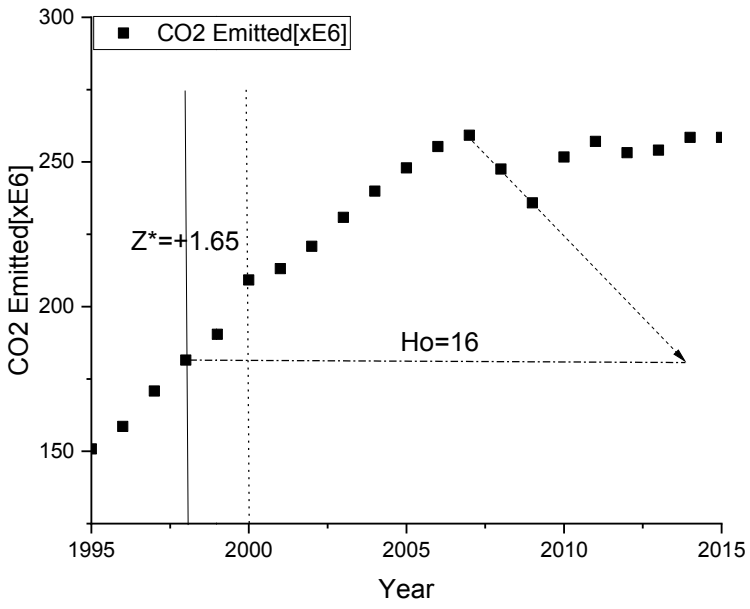

Fig. 4. Coal used percentage and CO_2 emission amount in Taiwan from 1995 to 2015

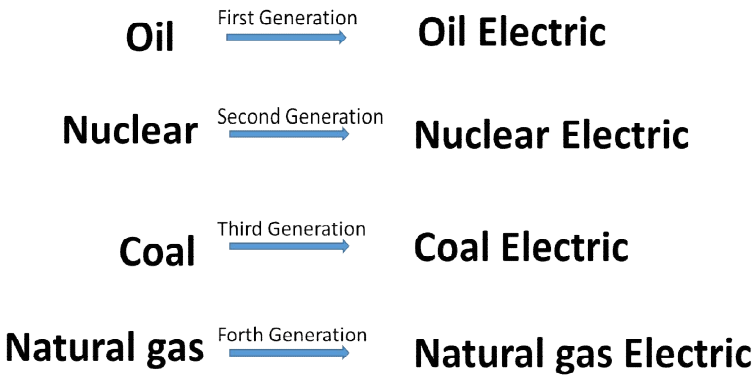

Fig. 5. The proposed proportion process (generation evolution) for electric energy sources

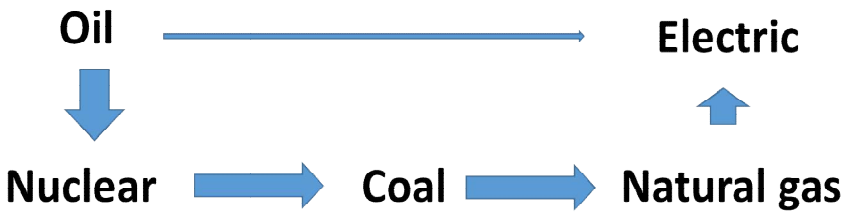

Fig. 6. The proposed disproportion process (generation coexist) for electric energy sources

4. CONCLUSION REMARKS AND POLICY IMPLICATIONS

This study explored that the use of the coal is the key issue for CO_2 emission. This fact is consistent with the conclusion of the literature [10]. From Taiwan's emission data, we also find that the plateau region formed when nuclear energy as base-load power has been sequentially replaced by coal since 1987. The total consumption amount of coal in Taiwan has been kept at 60,000,000 to 62,000,000 tons per year after 2005. The nuclear energy event of the Chernobyl disaster, which occurred in 1986, was the initial driving force for stopping the use of nuclear energy as base-load power and is also proposed as contributing to the exogenous event transforming into an endogenous policy [6].

COMPETING INTERESTS

Author has declared that no competing interests exist.

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