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# How government policies affect the export dynamics of renewable energy technologies: A subsectoral analysis

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## ABSTRACT

This study explores the long- and short-term dynamic relationships between government policies and exports of renewable energy technologies (RETs) at the subsector level (biomass, wind, and solar energy technologies). This allows a more robust exploration of the relationships, in which differences in cost structures and maturity levels exist for different RETs, without losing the generality of the results. Dynamic panel econometric techniques are employed to analyze the relationships, using data of annual measures for 18 countries during 1992–2008. The vector error correction mechanism (VECM) is used to test the dynamic relationships among government policies, exports, and gross domestic product (GDP) for biomass and wind energy technologies, and the vector auto-regression (VAR) model, for solar energy technologies. The study indicates that each subsector has a unique path-dependent process, showing the presence of different positive feedback mechanisms based on interactions among technology-push policy, market-pull policy, exports, and/or GDP in the short and long run. We suggest some policy implications based on the results of this study.

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## 1. Introduction

As an engine of the new development paradigm, renewable energy technologies (RETs) are expected to play a bridging role between a prospering economy and environmentally sustainable development. Developments in the global RET market have been monitored in numerous studies [1–5]. Several studies predicted that in 2010, more than 20% of global electricity generation would come from renewables and that the share of renewables in electricity generation would reach 31% in 2035 [3–5]. The global market for RETs and the transboundary movements of its components continue to grow substantially. This is because RETs are regarded as being aimed at achieving environmentally sound and sustainable development (ESSD), wherein economic development would be harmonized with environmental protection. Economic development essentially requires more energy, which demands that close attention be paid to energy security issues. In addition, there is

increasing global concern over environmental problems, including climate change, and global attention on linkages between trade and the environment. These issues as an international pressure have urged countries to conduct economic activities based on environmental considerations, such as the abatement of greenhouse gases (GHGs).

In this context, the RET sector is regarded as being economically strategic and has attracted great political interest worldwide. Governments support RETs in order to achieve the 3E (energy, environmental, and economic) goals [6] by reducing their dependence on imports of ever scarcer and more expensive fossil fuels, helping to stem climate change, and enhancing high export potentials in a growing international market [7]. Government policies have been instrumental in the recent growth in renewable energy [5,8]. Nonetheless, there remains substantial room for cost reduction and performance improvement due to the relative immaturity of renewable energy technologies compared to fossil fuel alternatives [9]. From this perspective, there is likely to be an expansion of government policy interventions to reduce costs and thus, create the potential for technological innovation and diffusion, and thereby a larger market share. Renewable energy subsidies jumped to \$88 billion in 2011, 24% higher than in 2010, and need to rise to almost \$240 billion in 2035 to achieve the trends projected in the

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New Policies Scenario [5].<sup>2</sup> The increasing attention given to energy issues and the national policies needed to achieve sustainable economic growth have stimulated research on the link between government policies and economic performance in the RET sector. As continuous improvements in export performance in ensuring industrial growth become more important than ever, the question of whether renewable energy policies may eventually lead to exports on the global market has driven economists to study the interrelations between government policy and export performance.

Existing empirical studies have contributed to the discussion on and the understanding of the relationship between government policies and exports of RETs by performing descriptive analyses and exploring case studies [1,3,10–16], and by conducting cross-sectional regression [2], time series [17], and panel analyses [7,18–22]. However, additional exploration can contribute to the existing literature in three ways. First, even though the literature has addressed the question of how government policy affects international trade, a comprehensive review of such studies does not exist at this time. Thus, this study attempts to review and identify the common elements and the implications of previous studies, specifically in terms of RET exports and the role of public policy in the sector. Second, most researchers have employed two-, three-, five-, or six-aggregate data on RETs. However, given the difference in the cost structures and maturity levels among different renewable energy sources, it is likely that the effects of policy measures on exports will vary across energy sources/subsectors [2,12,23]. Hence, in order to implement effective policies suited to each subsector-specific situation, further investigation should be conducted using data on different subsectors of the RET field. In this context, the current study deals with the issue at the RET subsector level, as analysis at this level allows a more robust exploration of the effects of government policy on export performance, without losing the generality of the results [22]. Third, with the exception of Costantini and Mazzanti [22] and Sung and Song [7], literature on the dynamic relationship between government policies and RET exports remains sparse. In particular, it is important to investigate the long- and short-run dynamic relationships between government policies and exports, especially considering that most of the panel data used in such studies are heterogeneous and non-stationary co-integrated, and that there are dynamic effects in exports [24–27], production process [28], policy [29] (i.e., path dependence, which means that contemporary inputs are, to some extent, invested for future outputs), and in the interactions among them [30–35]. This calls for a dynamic approach to exploring the relationships between government policies and RET exports. Notably, it is important to consider that there might be a structural break or cross-sectional dependence. Such issues should be taken into account before establishing an empirical model; the applicability of tests for stationarity and co-integration in panel data depends on whether the panel tests allow for structural breaks and/or cross-sectional dependence. In this regard, a systematic approach is lacking in previous studies. Thus, the current study examines both long- and short-run dynamics while systematically applying the dynamic panel approach.

This paper is organized as follows. Section 2 provides a literature review on the relationships between government policies and RET exports. Section 3 discusses the theoretical model and assumptions of this paper and presents a description of the data. The empirical

results are presented and interpreted in Section 4. Section 5 summarizes the main findings and lists the implications and limitations of this study.

## 2. Literature review

Three approaches have emerged in empirical studies that analyze how government policies affect international trade in RETs (Table 1).

The first approach is based on the multivariate cross-sectional regression model by Jha [2], who proved that an exporting country's policy support plays a crucial role in promoting its export performance in the RET market. She estimates that a composite variable composed of feed-in tariffs (FITs) and the share of renewable energy to the total energy supply may contribute to an increase in exports of aggregate renewable, solar, and wind energy technologies, and of undenatured ethanol, with the coefficients 0.410, 0.946, 0.976, and 1.710, which are significant at 1% or 5%, respectively. The second approach, based on the vector error correction model (VECM), is used by Algieri et al. [17]. They analyze the trade specialization dynamics of the global solar photovoltaic (PV) sector using time series data. They estimate that a 1% increase in price reduces solar PV exports by 1.15% in the long run and suggest that the relative price should be interpreted as an indicator of competitiveness in solar PV exports. They also indicate that foreign income is one of the major factors driving solar PV exports. According to them, since income elasticity exceeds unity, solar panels are regarded as "superior" goods, and thus, an increase in income is expected to raise demand for exports substantially. They find that although the trend variable is significant, its impact is less pronounced than that of the other variables, and suggest that other factors such as consumer preferences and public incentives play a minor role in encouraging exports. The third trend is the most recent in the literature. It explores the nexus between government policies and RET exports by analyzing panel data using the static and dynamic panel approaches. The static panel approach follows mainly the panel gravity model [18–21]. These studies test the effect of government policies on exports by inputting policy variables (environmental regulations and/or renewable energy supportiveness) and/or national innovation system-related variables of exporting and/or importing countries into the general stochastic formulation of the gravity model. The model has general parameters for trade analysis between two countries, such as incomes and populations of the exporting and importing countries, and distance and existence of common border between the countries. The policy variables include carbon dioxide (CO<sub>2</sub>) emissions, expenditure on environmental protection and taxes (used as proxy variables for a country's environmental regulation), public R&D expenditure, existence of incentive tariffs, and obligations and tax measures for RETs (used as proxy variables for renewable policy supportiveness). Overall, we find that the exporting country's R&D expenditure directed at each renewable energy subsector has a positive effect on exports of solar energy technologies, but does not have a significant effect on exports of wind energy technologies [19–21]. Incentive tariffs of exporting and importing countries also help to promote bilateral trade in solar energy technologies [19,21]. Obligations that require suppliers to provide a specific production quantity or percentage from renewable sources through quota systems or targets, however, do not significantly affect bilateral trade in RETs. Environmental regulations of exporting and importing countries become drivers in promoting bilateral trade in solar and aggregate RETs [18–20]. Gross domestic product (GDP) serves as an indicator of the sizes of the exporting and importing countries. As a socio-economic variable that represents the market size of RETs based on the demands for exports and imports, GDP has a largely positive

<sup>2</sup> This is one of three scenarios (namely "450," "Current Policies," and "New Policies") presented in the IEA [5], which takes account of broad policy commitments and plans that have been announced by countries, including national pledges, to reduce GHG emissions and phase out fossil energy subsidies, even if the measures to implement these commitments have yet to be identified or announced.

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