



# Financial development and energy demand in the United States: New evidence from combined cointegration and asymmetric causality tests



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## ABSTRACT

This paper applies a newly developed LM unit root test based on residual augmented least squares (RALS) regression under structural break and Bayer–Hanck cointegration approach to explore the integrating properties and to check whether a long run relationship exists among energy demand, financial development, economic growth, foreign direct investment (hereafter FDI), trade and capital using the United States dataset spanning over a period of four decades of 1973q1–2014q4. The results reveal cointegration among the series. Also, we find that financial development, FDI and real GDP reduce energy demand, while energy demand is positively affected by trade and capital in the long run. Moreover, real GDP and capital have an inverse impact on energy demand, while financial development, FDI and trade stimulate energy demand in the short run. Using a recently introduced asymmetric causality test, the results show that real GDP, FDI, trade and capital Granger cause energy demand in the long run, while a feedback effect is found for FDI and trade. This study opens up new insights for policy makers to maintain financial development and sustain economic growth in the United States.

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## 1. Introduction

A number of studies have recently been devoted to explore the dynamic link among energy demand, economic growth and financial development. In a sense, the focus also highlights the importance of the financial system in the energy-growth nexus (e.g., [3,19,39,47]). The identification of financial development among the mentioned variables in various empirical studies have become more important since a lot of financial institutions including banks and insurance companies were forced to declare bankruptcy or seek government bailout due to the great recession of 2008 in the United States. In order to understand the potential short and long term impact of the financial crisis on the United States economy better, it is important: i) to define correctly the financial development's term, and ii) to know the real relationship between financial development, economic growth and energy demand. At this level, several studies have shown that financial development can lower energy consumption as a result of higher

efficiency in its use (e.g., [19,36,37,47]).

Thus, the objective of the paper is to explore the short-and-long run estimates as well as the direction of causality among energy demand, financial development, economic growth using FDI, trade openness and capital as additional variables for the United States. Our research contributes to the financial development-growth-energy demand literature in several ways. First, we investigate the nexus in the United States, which has received limited attention in the literature [3,9,19,47]. The country is not only one of the largest consumer of energy but also has a well-developed financial system [48]. Secondly, in order to produce robust estimates, we use recent econometrics techniques including the residual augmented least squares (RALS-LM) unit root tests of [29]; the cointegration test of [6] and the causality test of [18]. The RALS-LM method combines the merits of both exogenous and endogenous unit root tests. Unlike most of the existing linearity unit root tests, the method is robust in the presence of nonlinearity. The RALS-LM procedure provides for any evidence of non-normality, including asymmetry, non-linearity, and fat-tailed distributions. To our knowledge, this is the first empirical attempt that uses the RALS approach to investigate the nexus. This [6] test has better small sample properties and is more reliable than the single cointegration

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test, which often produce conflicting results. The causality test of [18] provides for asymmetries, which is a normal phenomenon in financial data. Thirdly, we include several additional variables including FDI, trade openness and capital as additional variables into the equation in order to reduce omission variable bias. As is commonly known, omitted-variable bias problem can cause biased and inconsistent coefficient estimates of the variables as well as the direction of causality among the variables (e.g., [24,27]).

The rest of paper is organized as follows. Section 2 reviews the existing literature; Section 3 states data, methodology and empirical results; and Section 4 concludes with policy implications.

## 2. Literature review

Financial development determines economic growth through technological progress and capital accumulation by mobilizing and pooling savings, increasing the savings rate, facilitating and attracting foreign capital inflows, providing information about investment, in addition to optimizing capital allocation. For the energy sector, financial development can provide the necessary liquidity to stimulate energy projects and the availability of energy is also vital for financial institutions, which need energy as one its essential inputs. Growth in financial sector promotes availability of resources for investment purposes that lead to industrial growth and expansion of the production base. Financial development promotes industrial growth, helps to create new infrastructural facilities; and therefore positively influencing energy consumption [19]. Others highlight the environmental effect of financial development (e.g., [39,45]).

The empirical literature on the connection between energy and financial development has usually been studied through the energy-growth framework with financial development entered as a control variable in order to avoid omission of variable bias (e.g., [3,36–38,11,19,40,41,46,47,9,42]). The literature can be divided along different orientations but in this paper we categorize the studies into two strands. The first part contains studies that have used panel data framework and the second, strands that have used time-series dataset. The panel data papers include [36] who investigated the impact of financial development on energy consumption in 22 emerging countries over the period 1990–2006. Using the system Generalized Method of Moments estimation procedure, the author found evidence for the positive impact of financial development on energy consumption in these countries [37]. investigated the relationship between financial development and economic growth for nine Central and Eastern European countries. The author exposed the existence of significant connection between the variables and also that financial development has positive impact on energy consumption [11]. analyzed the relationship between financial development and energy consumption for the European Union employing the system Generalized Method of Moments estimation method. The authors showed that financial development promotes energy consumption but the magnitudes depend on the measure of financial development.

Al-mulali and Lee [3] explored the existence of a long run relationship between energy consumption, financial development, economic growth, urbanization and trade openness in the Gulf Cooperation Council Countries whilst applying Pedroni cointegration method. These authors found financial development, economic growth, urbanization and openness to have long run positive effects on the energy consumption. In addition, they indicated two-way causality among energy consumption and economic growth, financial development and economic growth, trade openness and economic growth, openness and financial development, and openness and urbanization. In addition, an evidence of unidirectional causality is found from financial development to energy

consumption as well as from urbanization to energy consumption [9]. examined the impact of financial development on energy consumption in 53 countries. The results show that financial development boosts energy consumption in developing countries but decreases energy consumption in developed countries.

Relative to time series data techniques, the methods of panel data papers are known to produce more degrees of freedom, more variability, greater efficiency in estimation and less susceptible to the problem of multicollinearity [43]. They might be inappropriate because of the following factors. First, panel data methods are centered on the assumption of homogenous relationship across the cross-sections, which ignores the differences, dynamisms and complexities associated with economic behaviour. Similarly [4], suggested that homogenous relationship may not always occur because of the differences in incomes, structures and demographic attributes. Relying on Monte Carlo experiments [35], and [30] showed that estimation results are likely to be biased when heterogeneity is present in a panel model with a small cross-section (N) dimension. Besides [28], suggested that panel data techniques can be inappropriate in the presence of heterogeneous cross-sections. Second [13], claimed that the quality of data differs in various nations, thus cross-sectional and panel data analyses are not likely produce robust outputs. Thus, country-specific study with time series data analysis is more appropriate when cross-section element of a panel data is finite such as the present study (N = 1).

Arising from the inadequacies of the panel data techniques, there are studies that have used time series approach to investigate the impact of financial development on energy consumption [38]. analyzed the linkage between energy consumption, economic growth, financial development, industrialization and urbanization, whilst applying the ARDL approach to cointegration and the VECM Granger causality test on the data of Tunisia. After observing the cointegration among these variables, the authors found the evidence of two-way causality between financial development and energy consumption as well as between industrialization and energy consumption, and industrialization and financial development [19]. revealed the presence of long run relationship between energy consumption, financial development, aggregate production and population using ARDL bounds test. In addition, they supported unidirectional causality from economic growth as well as from financial development to energy consumption in both short-and-long run [40]. found that financial development, energy consumption, economic growth, trade openness and capital are cointegrated for the case of China using ARDL and the VECM Granger causality approaches. Furthermore, the authors revealed bidirectional causality between openness and energy consumption as well as between financial development and energy consumption. Also, energy consumption was found to Granger cause economic growth. Last, they indicated that energy consumption, financial development and trade openness stimulated economic growth at a statistically significant level [41]. examined the impact of economic growth, financial development and trade openness on energy intensity using Indonesian data. They found that financial development Granger causes energy consumption.

Tang et al. [46] investigated the impact of financial development on electricity demand in Portugal. Their results indicated that financial development positively impact electricity consumption and unidirectional causality is running from electricity demand to financial development [47]. investigated the presence of long run relationship between energy consumption, economic growth, relative price, financial development and FDI for Malaysia whilst applying the Johansen and Juselius cointegration procedure. After revealing that the variables are cointegrated, the authors showed two-way linkage among energy consumption and economic

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